Competition *via* Investment, an Efficient Model for FTTH Rollout

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Abstract: The debate on the regulation of Next General Access started in Europe several years ago. It addresses the question of whether or not fibre access networks should be subject to the same regulation as the copper local loop. This debate is often examined as competition *vs*. investment. The present paper suggests that the best way for regulation to solve the dilemma is to promote competition through competitive investments in the fibre access market. In particular a combination of individual and co-investment from/among competing fibre operators could provide the desired outcome in terms of efficient investment, coverage, competition, innovation and prices/cost. Such an option corresponds to the choice of several European national regulators. It is also the the historical and highly successful option used in European mobile markets.

Key words: NGA, FTTH, Regulation, Competition, Dynamic and Static Efficiency.

The debate regarding the regulation of Next General Access started several years ago in Europe. It addresses the question of whether or not fibre access networks, scheduled to replace copper pairs in fixed local loops to allow the continuation of traffic growth, should be under the same regulation as the copper local loop. In particular, should the mandatory unbundling of fibre local loops at cost oriented prices be imposed to fibre operators by Regulatory Authorities?

The debate on this question at the European level has gone through several stages. In 2007, there was a consultation on NGA regulation by the European Regulatory Group and adoption by the European Commission (EC) of the Recommendation on Relevant Markets. In 2008, consultation on the first draft EC Recommendation on NGA regulation and at the same time, legislative debate regarding NGA regulation in the European Parliament and Council in the context of the Review of the electronic communications package. In 2009, there was a new consultation on a second draft EC

(*) The paper presents the views of the author and does not necessarily reflect positions of France Telecom. The author thanks the anonymous reviewers for their relevant remarks.

Recommendation on NGA regulation, quite different from the first one, and the conclusion of the legislative debate with the adoption of the Review of the Framework in December 2009. At the same time as this present paper is being drafted, a third version of the EC Recommendation is currently under discussion.

Nevertheless, the outcome of this intense European regulatory activity in terms of fibre investment incentives appears limited. Milestones are the explicit inclusion of fibre local loops in the European Recommendation on Relevant Markets in 2007, and also provisions for NGA rollout in the Review of the European Framework adopted in 2009, notably investment in modern infrastructure defined as a policy objective, and acknowledgement of symmetrical access remedies or risk-sharing access contracts as relevant regulatory tools. In the meantime, relevant decisions have been taken by National Regulatory Authorities concerning the regulation of their domestic access markets. However, the deadlock of the European regulatory debate is currently mirrored in the very limited deployment of fibre in Europe, and an ever-increasing gap as compared with Asia and the United States of America. The main reason for this situation may be that Europe is trying to find an impossible regulatory formula:

- If regulation imposes a fully non-discriminatory access regime to fibre investments, it means that non-investors have exactly the same rights to use fibre investments as investors, and benefit from exactly the same technical and economical conditions. **In which case investing, as opposed to not investing, will provide no advantage to investors**.

- Yet, potential fibre investors will only invest if they are convinced that investing will lead them to a more profitable situation than not investing. Therefore investment can only take place if **it garantees an advantage and motivates investors to invest**.

Unconditional application of these contradictory principles may not provide a practical regulatory solution. On the contrary, the necessity of trade-offs between conflicting objectives has to be acknowledged. National regulation should strike a balance between objectives and in order to do so, should/needs to take into account the actual market situation and the priorities of their development.

The NGA regulatory debate is often examined as competition *vs*. investment in the fibre access market. The purpose of the present paper is to suggest that the best way for the regulatory framework to solve this dilemma is to promote **competition through competitive investments** in the fibre access market. In particular, a combination of individual and co-investment among competing fibre operators could provide the desired outcome in terms of efficient investment, coverage, competition, innovation and prices. Such an option corresponds to the choice of several National Regulatory Authorities such as ARCEP in France or Anacom in Portugal [1]. It was adopted with a high success rate in the European mobile markets. It is also the standard situation in a great majority of technological industries all over the world. The fibre-investment cycle appears as a unique opportunity in decades to definitively transform electronic communications into a modern, mature and competitive industry. This opportunity should not be lost.

The first section highlights the importance of dynamic-efficiency effects in electronic communication industries, supported by recent results in technical progress regarding information technology reported in economic literature and by more specific attention to the technical content of fibre rollout. This element is critical to accurately assess the likely performances of the major regulation and competition scenarios concerning FTTH rollout. It concludes that provided that non discriminatory access to legacy bottlenecks is guaranteed, the most efficient solution, in terms of outcomes for the market, will combine infrastructure competition between vertically integrated fibre operators for the feeder portion of FTTH networks, and symmetrical access via risk sharing or co-investment contracts between fibre operators for the terminating segment of FTTH networks.

In the second section, we explain why FTTH access areas, are either competitive, allowing several fibre operators to compete (black areas in the European Commission's terminology) or non-profitable even for a unique fibre operator (white areas in the European Commission's terminology). Areas for which a single fibre network would be profitable, but not several (grey areas in the European Commission's terminology) are necessarily a minor proportion of the access market and should not be the focus of the regulatory policy. Public funds should be dedicated to white areas and devoted to covering specific fixed costs in order to convert white areas into competitive areas. Finally, we suggest that a fibre market structure comprised of a few fibre access network operators is the appropriate structure to deliver innovation, large scale coverage and low prices which will lead to high penetration.

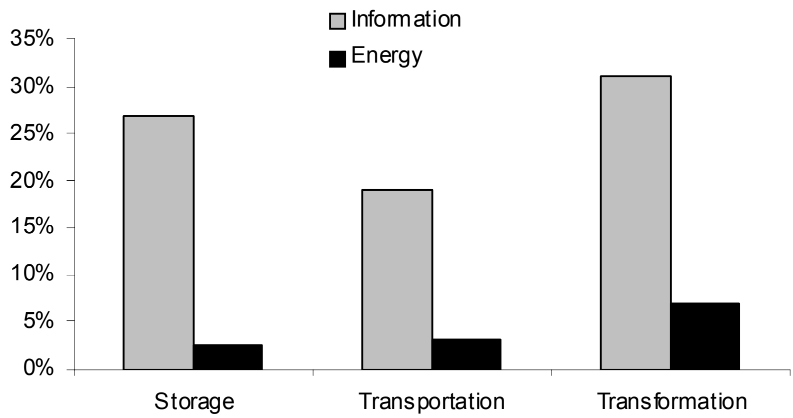
[1] Other NRAs such as OfCom in the UK take the opposite model of a separated infrastructure monopoly.

Reaping the benefits of the effects of dynamic efficiency should be the priority of NGA regulatory policy

Technological progress in information technology

The works of Heebyung Koh, Christopher Magee and Mario Amaya of MIT assess technological progress in both information and energy technologies over the past 100-150 years. The technological progress of the former (from 20 to 30%) is much more important than for the latter (from 2 to 7%), as illustrated in the figure below:

Figure 1 - Annual rate of technological progress (1850-2004)



Further analysis has shown that the annual rate of progress for the throughput of wireless technology reached 51% since the development of cellular service, i.e. for 30 years. This trend seems set to continue in the short and medium term.

Obviously, these results are very general and do not directly apply to the specific case of fibre-access network rollouts. However, they substantiate the general message that dynamic effects are of paramount importance in information technology in general. Regulatory rules built on the research of pure static efficiency considerations and which ignore dynamic efficiency issues are prone to be substantially wrong.

If we analyse the potential impact of technical progress in fibre access rollout, the following elements should be taken into account:

- The large time-scale and the huge volumes needed for nation-wide fibre rollouts will allow learning curves and technological advances to impact the total cost of fibre access networks to a great degree, even though each piece of fibre access infrastructure may not be individually replaced before decades.

- Conventional wisdom mainly considers fibre rollout as a manpower activity, workers digging kilometres of trenches. This is not an accurate image, in particular where there is enough availability in existing ducts to accommodate fibre deployment, as it is the case in France. When ducts have been built for copper cables, available room for fibre cables in those ducts should not come as a surprise for anyone who has compared the very small diameter of fibre cables to the large diameter of copper cables. In France, statistics as well as experience have shown that, provided existing ducts are used efficiently, nearly no capacity investment in civil works will be needed. This may not be the case in all countries. For instance, there are no ducts in the Netherlands. In the UK, following the study by AnalysysMason for Ofcom, significant reinvestment in civil works appears to be needed for fibre, apparently due to the bad physical state of some portions of the infrastructure more than to the lack of available space. High technical progress in civil works itself is unlikely. However, technical progress may influence over time the quantity of civil works needed for a given length of fibre infrastructure.

- The exact nature of fibre investment expenses should be analysed in more detail for the sake of the regulatory debate. It will reveal that these expenses including, among other things, procurement of fibre cables, engineering studies, information system evolution and management, definition and control of rollout processes and the rollout itself, with its specific techniques. All these elements may benefit from technological progress all along the rollout process which may take between 10 to 20 years.

- To check this, the existing level of technological progress in the rollout of classical fibre infrastructure for backbones or backhaul transmission should be considered. It will be seen that, although the volumes are very small compared to FTTH, and that the technology can be considered as mature, as backbone and backhaul fibre cables have been deployed for more than 25 years, there is still a significant evolution of the unit price of transmission fibre rollout per year.

These elements indicate that more attention, both in terms of analysis and in terms of policy, should be paid to the dynamic efficiency potential in fibre access rollout, especially when under competitive pressure.

Infrastructure competition and risk sharing through co-investment are the only models able to capture the dynamic efficiency effects which are critical for FTTH success

This section is meant to compare different FTTH investment and competition models, regarding their scores in terms of product innovation, process innovation, coverage, consumer prices and choices.

Options for investment and competition in FTTH networks

The different options regarding FTTH investment and competition models are infinite. However, from the current regulatory debate, it is possible to characterise 5 major options:

- (1) Competitive private investments.
- (2) Private investments by a single undertaking with risk-sharing or co-investment access contracts for competitors.
- (3) Complementary private investments with voluntary reciprocal access between competitors.
- (4) Private investments by a single undertaking with traditional, unconditional price per access for competitors.
- (5) Separation of the access activity (utility model).

Options (2) and (3), described above, are relatively close/similar and may sometimes coincide in practice: voluntary reciprocal access may be proposed under risk sharing conditions, whereas private investment by a single undertaking may concern only a proportion of areas, other areas being covered by another undertaking.

A single option may not be optimal for all geographical areas, and in each geographical area a single option may not be optimal for all elements of the fibre access network. For instance, it is commonly acknowledged that infrastructure competition within/inside buildings is not a reasonable option. In France, the regulation defined by ARCEP imposes a unique terminating segment, from the so-called "point de mutualisation" (mutualisation point) to the subscriber's premises. In very dense areas and for buildings with twelve homes or more, ARCEP considers that the mutualisation point may be located in the building. Outside very dense areas or for buildings with fewer than 12 homes, ARCEP considers that the mutualisation point should be located outside buildings and serve a reasonable number of buildings. The precise definition of what is a reasonable number of buildings, is still under examination at this point in time. The different versions of the draft Recommendations of the EC on NGA regulation also refer to the concept of terminating segment of the fibre local loop, as opposed to the feeder part: the terminating segment goes from the "Distribution Point" in the EC terminology to the subscribers' premises, and the feeder part goes from the first optical network node to the "Distribution Point".

Features to evaluate the five options

The features which characterise the different options, and which will serve as criteria to score the global performance of each option, can be summarised as follows:

- static cost efficiency, for a given technology: the static extra cost of duplication compared to mutualisation;
- dynamic cost efficiency, related to process innovation: the capacity of the option to enhance faster learning curves for operational and rollout costs, and higher technical progress to minimise cable and equipment costs;
- incentive for extending the geographical coverage: are operators in a process which maximises their incentive to extend their geographical coverage, or are they better off concentrating on the densest zones?
- demand oriented retail prices: have operators' enough freedom to adapt their price structures in order to meet the heterogeneous customer demand, or on the contrary, are they submitted to rigid constraints leading to "one size fits all" prices on the retail market?
- product and service innovation: do operators have a full end-to-end control of their technical chain and are therefore able to freely introduce product innovation for their customers, or, on the contrary, are their innovation processes impeded by slow multilateral administrative decision processes and minimal scope, if any, for service differentiation?
- incentive for achieving high market penetration: is the business model of retail operators based on de facto variable infrastructure costs, favouring low volumes and high margin or is the business model of retail operators based on de facto high fixed infrastructure costs and low variable infrastructure costs, favouring high penetration?
- low network entry barriers: is regulation optimised to favour network entry?

- low service entry barriers: is regulation optimised to favour service entry?

Static* versus *dynamic cost effects: a toy example

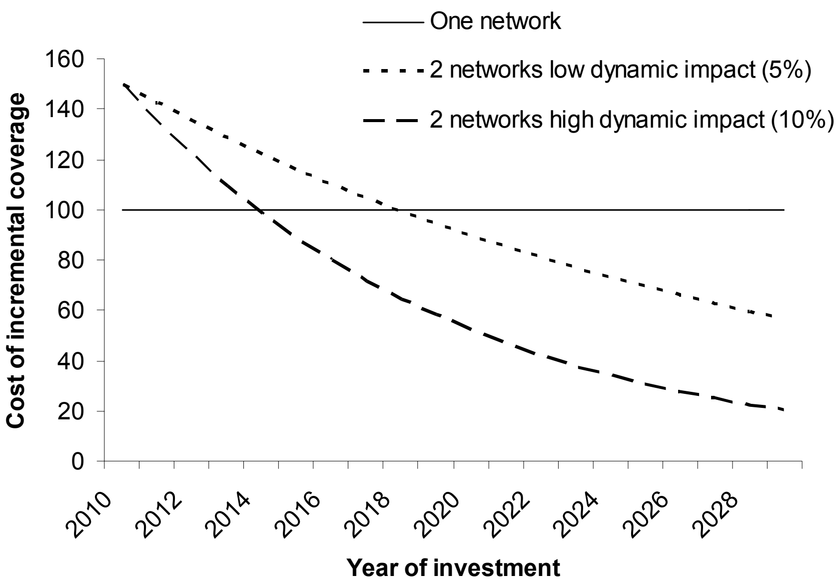
Before analysing how each of the 5 competition and investment options score in relation to the different aforementioned criteria, it is useful to take some time to elaborate on dynamic efficiency effects. In the previous section, the potential level of dynamic efficiency effects on fibre access rollout has also been emphasized. Dynamic efficiency effects, even without taking into account the long term issues of innovation and sustainable competition, may not be marginal when compared to static efficiency effects, regarding the overall cost of fibre rollout.

This can be illustrated with a toy example, comparing purely on a cost-basis, a single monopoly network *versus* two competing networks to serve the same demand.

This toy example is not meant to prove that dynamic efficiency effects always dominate static efficiency effects, but that the former cannot *a priori* be assumed to be negligible compared to the latter and that therefore both have to be considered for regulatory policy purposes:

- There have been numerous technico-economic studies on fibre access networks (Wik, AnalysysMason, IDATE, …) but all are based on a large number of ad hoc hypotheses and parameters. No generic studies give a robust and simple estimate of static efficiency loss when two fibre access networks are built instead of one. For the purpose of the present toy example, we will assume that two competing access networks have a static cost 50% higher than a single network: 50% being the average between the minimum extra cost, 0%, and the maximum extra cost 100%.
- The competitive pressure on network rollout activities may generate an additional minus 5% to 10% per year on learning curve and technical progress. This appears to be a conservative figure when considering the general level of technological progress in information technology, and also the specific level of technical progress already observed in classical fibre infrastructure rollout.
- Under such a hypothesis, the total cost of rolling-out two networks may prove to be lower than the total cost of rolling out one network, as illustrated in the depictive graph below, where the total cost in each case is the integral surface below each curve:

Figure 2 – Static *versus* dynamic effects



Existing quantitative studies about regulation and competition in fibre access have taken the implicit hypothesis that the fibre access cost function does not depend on whether or not fibre access is provided under monopoly or under competition. This is a bold hypothesis. It is in contradiction with the philosophy of European electronic communication regulation which considers competition as a powerful means to enhance efficiency. Cost studies on fibre-access networks comparing monopoly and competitive fibre access rollouts should take into account the benefit of competition in fibre rollout on the productivity of undertakings.

Approach for an evaluation of the investment and competition models

This paragraph analyses through a representative set of examples, how the 5 FTTH competition and investment options proposed above (p. 6). May be rated against the different features which have been defined above: static and dynamic cost efficiency, incentive for extending the geographical coverage, demand-oriented retail prices, product and service innovation, incentive for achieving high market penetration, low network or service entry barriers.

For instance, concerning the criterion "Low service entry barriers", the best option is a standard access obligation because there is no need to pay fixed or upfront-costs to enter the market. Also, the access infrastructure and products, as they have been defined by using information from the retail market are technically specified to be relevant to feed the retail market, thanks to the vertical integration of the access provider. The level of adaptation from the infrastructure to the needs of the retail market with the option "pure access activity" will not be as good and therefore it is ranked second. The third best option is the "risk sharing contract", which still allows an undertaking to enter the market without physically investing, but with a commitment of the access beneficiaries towards the access provider. The last two options do not allow market entry without investment. The fourth option is investing only in a geographical sector of the market for the "reciprocal access agreement". The fifth option is the "infrastructure competition" wherein the investment must address the defined market in its entirety.

If the example of the criterion "low network entry barrier" is considered instead of "low service entry barriers", then "infrastructure competition" appears to be first, because under these options, network rollout is given maximum facility and efficiency.

Infrastructure competition logically has the best ranking for all features, except static cost efficiency and low service entry barrier, for which it has the worst rankings.

The cost structure of the undertakings operating on the retail market, particularly regarding their fixed and variable costs has a particular impact on their incentive to have a large number of customers and favour a high and fast penetration of the service. With high fixed costs and low variable costs, there is a strong incentive to reach high penetration. On the contrary, with no fixed cost and high variable costs, the incentive is to have high retail prices on top of high variable costs, and service penetration is not a critical issue. In this respect, reciprocal access agreements and risk sharing contracts have similar cost characteristics as infrastructure competition: fixed cost as a counterpart of reduced variable cost. All three options give incentive to favour service penetration.

Risk sharing contracts, when compared to infrastructure competition, benefit from static cost efficiency but lose dynamic cost efficiency effects. Reciprocal access agreements, retain some of the dynamic efficiency of infrastructure competition, as several undertakings are rolling-out there own network. Reciprocal access agreements also benefit from static efficiency. However, reciprocal access agreements may not reach the same level of dynamic efficiency as pure infrastructure competition because this option needs strong technical and economical coordination between undertakings. All undertakings need to make compromises, adopt some form of second best solutions and cannot freely innovate in the portions of infrastructure which are under reciprocal access agreement. In-building fibre infrastructure in France illustrates this point quite well: even though there has always been a general agreement between the regulator and undertakings on reciprocal access, an operational agreement may just now be reached after more than 3 years of discussions. This proves that coordination and transaction costs are not just theoretical ideas but are also deeply felt in the real world.

By contrast, as far as retail pricing is concerned, the two options "standard access obligation" and "pure access activity" both have a very important drawback: they artificially transform actual fixed costs into apparent variable costs at the borderline of the access activity. This bias leads to overall poor pricing and investment decisions. In particular, it makes it impossible to apply efficient penetration and value pricing strategies. This severely limits the value which can be extracted from the market, and therefore decreases the incentive to extend the investment. It also severely limits the possibility to adapt prices to customer's willingness to pay, in particular for low value customers, and puts service penetration at a risk. This explains why they are poorly ranked on penetration and demand associated features.

Let's now more specifically consider the pure access activity option. Technically it will be a monopoly, and so it will not benefit from any competitive pressure to reduce costs. It will face hard coordination and conflicts of interest, related to investment and prices, between downstream and upstream. It will ignore information and incentives from the retail market and may take ill-informed decisions. Competing downstream undertakings which use purely upstream access activities will moreover have contradictory demands concerning investments, processes, coverage, technologies, interfaces and prices of the upstream monopoly. The only way to solve these contradictions may be either from the upstream monopoly to break non discrimination and favour one downstream operator, or from the downstream competitors to make agreements that risk not being fully compliant with article 101 of the Treaty.

Coverage will of course be better guaranteed with high dynamic efficiency and competitiveness among fibre operators to reach customers by extending their networks. On the contrary, of course, pure access activity or standard access obligation options mean no pressure for technical efficiency nor competitive incentive for coverage, rigid retail pricing and therefore low coverage.

Basic comparison of the investment and competition model regarding all criteria

All these considerations are summarised in the table below. Each figure in the table is meant to rank the different competition and investment options regarding the different features being considered. Then rankings have been added on all features in order to identify the best overall options. Figures given in the table are rankings: lowest figures correspond to best options; highest figures correspond to the worst options.

On a scale of one to five, the sum of the rankings is 15, which is written on the bottom line of the table. The rankings have been written in such a way that all considered features have the same total weight of 15, even in the cases where several investment options appear to be fairly equal regarding a feature and therefore have the same ranking in the table.

As illustrated in the chart below, in order from highest to lowest the global ranking is: infrastructure competition, risk sharing pricing, reciprocal access agreements, standard access obligations and pure access activity.

Table 1 – Comparison of competition models

Rank	Static cost efficiency	Dynamic cost efficiency	Incentive for coverage	Demand oriented retail prices	Product innovation	Market penetration	Low network entry barriers	Low service entry barriers	Unweighted total ranks	**Global Rank**
Infrastructure competition	5	1	1	1	1	1	1	5	16	**Best**
Risk sharing contract	2,5	3	3	2,5	2	2,5	2,5	3	21	2nd
Vol complement invest + reciprocal access	2,5	2	2	2,5	3,5	2,5	4	4	23	3rd
Standard access obligation	2,5	4	4,5	4	3,5	4,5	2,5	1	26,5	4th
Pure access separated activity	2,5	5	4,5	5	5	4,5	5	2	33,5	**Worst**
Total	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*		

Obviously, if this evaluation model is used on a more practical basis, the different criteria should be weighted carefully, and will depend on the particular piece of investment concerned, on whether the investment takes place in dense or non dense areas, or on whether it takes place at the beginning of the learning curve or later, when technologies and processes have reached a certain degree of maturity. For instance, in the case of FTTH in-building wiring in dense areas, and more generally in the case of FTTH terminating segment, as defined in EC draft NGA Recommendations, the total cost is so high, including the cost for the industry but also the transaction costs with all concerned stakeholders, such as landlords and local authorities, that static efficiency is a dominant concern. Therefore infrastructure competition is excluded in such a case. But the profitability of such an investment is highly dependant on fast market penetration and of demand oriented prices. Therefore risk-sharing or co-investment contracts or complementary investments with reciprocal access are the only efficient solutions this case. This is the option which has been chosen in France by ARCEP for in-building fibre in very dense areas.

■ Except for the terminating segment, FTTH infrastructure competition is a realistic option outside non profitable areas, and would lead to low prices, high coverage and strong innovation

The first part of this paper has shown that whenever possible, outside the terminating segment, infrastructure competition should be chosen as an investment and competition model for FTTH. In this section, we will show that infrastructure competition is indeed economically sustainable except in non profitable areas at least in France. The intermediate areas, where only a single FTTH network would be profitable, represents only a limited, less than 12%, and unstable proportion of the market.

If regulation allows FTTH infrastructure competition to flourish, completed by risk sharing or co-investment access contracts for the terminating segment, the fibre market structure will become close to market structures observed in the European mobile industry, with between 3 to 5 infrastructure competitors delivering high investments, high coverage, high penetration, affordable prices and high innovation.

In France, areas where an FTTH access network is a profitable natural monopoly, should represent 12% or less of the national access market. In European Competition Law terminology, they are known as "grey areas"

A critical parameter for investment and competition in FTTH access networks is the number of parallel access networks which can be simultaneously profitable in a single local area.

In this regard, the recent guidelines for State Aids for Broadband and NGA coverage Law [2] define three categories of areas:

- "black" areas, where at least two parallel access networks can coexist and be profitable at the same time and where there is, *a priori*, no market failure. The European State Aids guidelines text explicitly classifies as competitive areas where at least two competitive NGA infrastructures are deployed; whereas the second version of the EC draft Recommendation on NGA regulation tends to request three or even four parallel infrastructures for an area to be declared competitive.
- "grey" areas", where only a single network can be profitable [3] and where regulation is needed to compensate for the absence of infrastructure competition; however, regulation should be fine-tuned to keep investment incentives alive otherwise, regulation will turn "grey" areas into "white" areas,
- "white" areas, where even a single network would not be profitable and therefore no private investment can be expected. Public subsidies are necessary to obtain fibre coverage.

"Black" areas and "white" areas are a common situation in a market economy and do not call for sector specific economic regulation: regulation by *ex post* application of competition law for "black" areas, in particular article 101 against collusion and article 102 against abuse of dominant position, State Aid rules or Altmark criteria for Services of General Economic Interest for "white" areas.

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[2] See "Community Guidelines for the application of State aid rules in relation to rapid deployment of broadband networks", Consultation of the European Commission May-June 2009, Indent (37).

[3] Or where only one, two or three infrastructures can coexist if we take the very demanding criteria expressed in the draft NGA Recommendation.

The situation of "grey" areas is more original in a market economy and may require specific asymmetric rules applicable to the owner of the single infrastructure.

From this stems the issue on whether or not commercial activities based on FTTH access networks may require a heavy-handed sector specific economic regulation, or, on the contrary, a light approach, depending on the proportion of "grey" areas, to "black" and "white" ones, in the total market. If "grey" areas represent a significant proportion of the total market, specific asymmetric regulation will play a major role in the regulation of FTTH services. If "grey" areas represent a small portion of the total market, then regulation should rely mostly on European Competition law.

The developments below show that the boundaries of "grey" areas are structurally limited by self-consistency constraints concerning the conditions of profitability of a fibre access network.

Applying these constraints to French local areas where FTTH networks are supposed to be installed, leads to the conclusion that **"grey" areas represent a maximum of 12%** of the total fibre access market. If black areas were defined by the presence of a minimum of three (resp. four) infrastructures, then grey areas would represent a maximum of 20% (resp. 25%) of the total access network. Moreover, the precise identification of where these grey areas are critically depends on varying cost and demand parameters.

Therefore in France, grey areas will represent a limited and unstable proportion of the market. Besides what is necessary to ensure non discriminatory network rollout cost conditions between FTTH operators, sector specific asymmetric regulation, which is only justified by the existence of "grey" areas, should therefore have a relatively limited weight to *ex post* competition law in the regulation of FTTH based services in France.

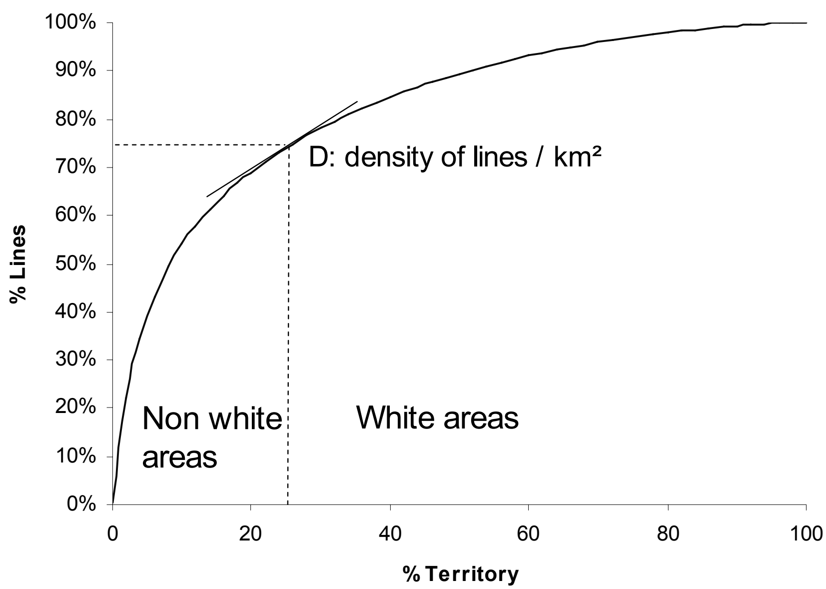
The lower density limit of black areas corresponds to areas twice as dense as the higher density limit of white areas

When calculating the potential profitability of an FTTH network, the most critical parameter to take into account is the household density per km² of the local area to be served. Of course, a detailed calculation of the profitability of a specific area would involve many other parameters, but for a global assessment of the profitability of FTTH networks in local areas, household density is the most critical. Therefore, we can characterise the borderline between "white" and "grey" where a single access network starts being profitable, by a threshold of density D households per km². Numerous studies on the cost of NGA networks as a function of households per km² or of specific geotypes by consultants such as Wik, AnalysysMason or IDATE, have been published. However, their results depend on a large number of parameters and hypothesis which are difficult to assess, each of which having a significant impact on the conclusion. For instance, Wik's study on NGA costs realised for ECTA and published in 2008, used for France the hypothesis that FTTH rollout would imply an investment in ducts for 20% of the infrastructure length. Such a hypothesis, which we now know to be inaccurate, predetermined to a large extend the conclusion of the study.

The approach proposed in this paragraph is different: it does not try to evaluate the absolute value of FTTH rollout cost, but to characterise as simply and transparently as possible consistency relationships between the profitability of FTTH investments in different contexts.

Let us assume that a local area will be profitable for a single FTTH network as soon as the household density is above D per km².

Figure 3 – White areas in function of lines concentration in France



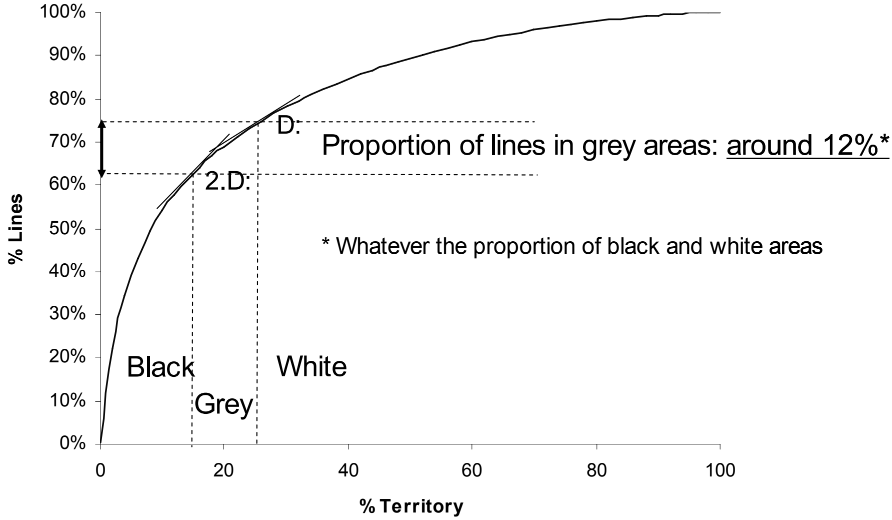
All other things being equal, if one FTTH access network may be profitable as soon as household density exceeds D customers per km², then two FTTH access networks may be profitable when household density exceeds 2.D per km². This is because, provided network operators are placed under non discriminatory conditions for network rollout and customer acquisition, each of the two operators may claim to have half the market on its network. Therefore each of the two networks benefit from a household density D per km² and per network, which is sufficient enough to be profitable:

- Concerning revenues, regulatory constraints which prohibit monopoly income allow the assumption that the average revenue per customer will be equivalent despite whether several networks serve the area or not. In an area of density **2D per km²**, 2 networks will therefore each have the equivalent revenue of a single network in an area of density D per km².

- Concerning costs, the total cost of two networks competing in an area of density 2D is, at most, twice the cost of a single network serving an area of density D. This is because, if the cost of an access network depends on customer density, which is the hypothesis suggested in the context presented in this study, building an access network in an area of density D costs C. If, in an area of density 2D, there are two identical networks each serving half of the total market, therefore each benefiting from a density D and if no costs are shared between the two networks, then each one will cost C and together they will cost 2C. Also, from a well-known propriety of concave functions, such as network cost as a function of density, if the market is not equally shared between the two networks, the total cost of the two networks will be lower than the total cost that would occur if the market was equally shared.

Therefore, the profitability limit for two parallel networks corresponds to a density of 2.D households per km² or lower. For the sake of simplicity, we will consider in the following lines that this threshold of profitability is simply equal to 2.D, which overestimates the weight of grey areas, those where a single network is profitable and where two would not be profitable. Hence, there is a mathematical relation between on the one hand, the minimal household density which is the boundary between white and grey areas, and on the other hand, household density which is the boundary between black and grey areas. The latter is inferior or equal to twice the former. Grey areas correspond to areas whose densities are between these two values. Using the actual concentration curve of lines in the French territory, and applying the mathematical relation described above, the interval between density D and density 2D represents 12% of the access line market:

Figure 4 – Black, grey and white areas in France



The empirical concentration curve of access lines in France is accurately estimated by a logarithmic curve. Therefore, the proportion of lines between density 2D and density D equals 12%, whatever the value of D.

Therefore if black areas are defined by the coexistence of two profitable networks, then grey areas, where a single network is profitable, represent 12% of the access market in France.

The above analysis about density 2D can also be applied with density 3D for three competing infrastructures (resp. 4D for four competing infrastructures). Using the same line concentration curve and using the same considerations, grey areas can be evaluated to represent 20% (25%) of the access market, if black areas need 3 (resp.4) competing networks. These estimations are without considering the benefits of infrastructure competition in terms of dynamic efficiency.

This calculation only concerns the technical part of the access network. Other elements of the technical network, such as: backhaul, transport, service platforms, as well as the commercial network, correspond to larger geographical scales. Therefore, demand appears less geographically concentrated and the effect modelled here appears weaker. However, these elements are already known to be competitive in France, except for a proportion of the backhaul networks serving non dense local areas. It remains to be analysed how many "black FTTH" local areas for which the backhaul market is not competitive there are. However it is unlikely that such case would modify the overall conclusion.

Expressed in qualitative words: French local areas are small and very heterogeneous: from 100 000 inhabitants to 50 inhabitants for a " constant size of 45 km². Conditions for an FTTH local area to be grey are very restricted: dense enough for one network but not for two (resp. 3 or 4). When restricted conditions are applied to a very heterogeneous population of areas, it is logical that only a very limited number of areas meet these conditions.

Grey areas represent a limited proportion of the FTTH access areas. Moreover, they represent a constantly changing target, as their precise locations depend on unpredictable demand and cost conditions. They should not be the focus of regulation (except level playing field conditions). Regulation should focus on facilitating infrastructure competition in black areas and the public coverage of the specific costs of white areas so that they can evolve into black areas.

Competition between fibre access operators will lead to an efficient market structure, delivering low prices, high coverage and strong innovation

If the recommendations discussed above are followed, the fibre market structure would probably lead to 3 to 5 fibre operators. Each of which will have its own fibre network in the feeder part of the access network down to a mutualisation point giving access to a unique terminating segment for all operators. Access to the terminating segment would be granted by the operator which has built it through risk sharing, co-investment conditions.

Such a market structure resembles mobile market structures in Europe, which over the last 20 years have proved to be among the greatest European industrial, financial and commercial successes ever in information technology.

In this final section, we will show why only such a market structure is likely to provide the desired outcome on investment, coverage, penetration, innovation and low prices for consumers. The objective here is not to argue that there is a precise analogy between fibre and mobile access cost structures, but to use the mobile historic example to show why a market structure made of a few infrastructure based competitors should deliver the desired outcome.

Infrastructure competition market structures will lead to lower prices for consumers

As shown in the first section technical progress in information technology in general and in information transportation in particular is very high. This technical progress will only benefit consumers if operators are able to continuously invest and incorporate the latest technologies into their networks. This implies a market structure which contemporaneously:

- allows the existence of adequate Ebitda margins in order to generate the necessary cash flows and favours rational, allocations of these cash flows to make network investments,
- requires undertakings to make these investments in order to remain competitive.

An "imperfect" competition between a few competitors has precisely these characteristics and leads to lower prices for consumers than a perfectly competitive market. "Imperfect" competition (prices above cost) leads to lower prices than "perfect" competition (prices = costs) because costs are lower in the former case than in the latter.

Infrastructure competition market structures will lead to large market driven geographical coverage, high service penetration and strong innovation.

Concerning geographical coverage, facts along with common sense converge to conclude that a race for coverage between competing infrastructure operators leads to the fastest, cheapest and largest market driven coverage. Mobile coverage was faster than any other technology thanks to infrastructure competition.

Concerning affordability and penetration, the results of the mobile model of infrastructure competition is crystal clear: by and large, mobile is the most affordable access to electronic communication world-wide. At the end of 2010, around 5 billion people will use a mobile access, more than 80% of the world population. In Europe, the universal mobile access has been obtained without any universal service obligation. This result comes from mobile infrastructure competition, each operator willing to attract the maximum number of consumers on its own infrastructure. Infrastructure competition has also allowed mobile operators to tailor more precisely their pricing structure to the diversity of their customers' demand, thanks to the absence of cost oriented wholesale access obligations which would have led to uniform retail pricing.

Infrastructure competition is also key in obtaining permanent product and service innovation thanks to the technical freedom enjoyed by competitive operators.

These key success factors of European mobile markets derive from the initial choice of infrastructure based competition and would probably not have been achieved if more conservative regulatory options had been chosen by public authorities.

■ Conclusion

The developments presented in this paper have shown that competition and investment in FTTH networks may be obtained through competition by investment as well as through symmetrical access obligations imposed to the terminating segment of FTTH network, under risk sharing or co investment contracts Such a competition and investment model would deliver fast and extended coverage, high penetration, low prices and strong innovation.

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