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# Impact of users' communities on broadband economics

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## Abstract

Both users and operators are aiming for faster networks to host higher-quality contents. Legacy infrastructure models are still mainly based into facilities investment competition. The large investment to deploy a new network into the market has been a huge barrier for new entrants and it has moved regulators to favor infrastructure sharing and unbundling models to seek for competition. Moreover, the in-building deployment problems and the high costs of civil-works are hindering the optical fiber deployment to the home.

On the other hand, the high demand for broadband creates new consumer habits towards digital contents and does not only rely on the network access technology to get connected. This need brings new opportunities for more innovative deployment models. This paper estimates the impact of having the end-users more actively involved in the deployment of fiber networks to reduce the overall investment.

The techno-economic model drawn in this paper is based in the self-aggregation of users to share a broadband connection. More precisely, the model consists of a neighboring community of users that decides to build their own in-building access network to share a single broadband Internet connection. Services that are offered over the top of the network are contracted individually by end-user. The model allows comparing the effect of users contracting their Internet access in an aggregated way (at community/building level) in a highly competitive scenario.

As noticed above, the expected effect of the involvement of users as a key element of a fiber network is to lower the overall investment up to a 45% mainly sustained by communities that will afford the in-building access network costs. The article analyzes the effect of users sharing a single connection that can lead to operator's reducing the risk and the length of the investment. It has been measured the investment length in terms of positive net present value, ROI over a certain interest rate and the payback period as the main indicators to explore how the higher engagement affects the deployment model in terms of risks and returns. In some cases, the investment periods increase by a factor of three or even can become non-sustainable if there is the pricing strategy ignores the aggregated demand.

In addition to the new access network scenario, the model has implications on pricing, which directly affects the return of investment from the operator's side. In that way, the paper also compares the effect of keeping the same pricing scheme for individual and user-aggregate retail offer, to another pricing scheme that differentiates the offers for single users and communities.

**Keywords:** Broadband; Techno-economic; FFTH; FTTH; Statistical multiplexing;

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<sup>1</sup> Dr. Oliver was a visiting scholar at MIT during 2013/2014.

## 1. Introduction

The growing broadband demand, see (Cisco VNI, 2013), generates new opportunities for non-traditional fiber network deployments that may disrupt the market. Most Fiber to the Home (FTTH) models consist of integrated vertical operators deploying the whole networking infrastructure, from carrier's premises to customers' households, requiring long-term investments. Two main drivers have traditionally triggered for a fiber deployment: a private deployment model aiming to maximize the profits and revenues trying to get an increasing market share; and a public deployment model aiming to provide universal broadband/Internet coverage in less-profitable, mostly rural, areas. Internet demand, including all types of digital contents, has been the main market driver for the growth of broadband at higher speeds and quality of service.

Traditional<sup>2</sup> deployment models have uncertainties and risks, as any business investment, most of them centered on which will be the demand growth<sup>3</sup>, how competitors<sup>4</sup> will react (prices, offers, new services) and how will the evolution of the technology affect the investment<sup>5</sup>. These models are based on careful estimation of the initial demand and its growth forecast along the time. Carriers analyze the potential customer's profile, whether residential or businesses, targeting an increasing market share for each area at the same time that the rollout is progressing. This share is based on single (household/business) broadband connection as the unit offer commercialized in the area. Thus, each household may get its own broadband access that is usually shared among the members living or working in the same served unit (household/business). In contrast to mobile broadband services where each access is not shared and used only by one user, the fixed broadband model gets a certain level of aggregation where members of the same family, or roommates may use, even simultaneously, the same Internet connection. Based on that assumption, most techno-economic models estimate the take-up rates in each particular area, as a fraction of the existing households and plan the whole networking infrastructure accordingly. Take-up rates estimations are fine-tuned using previous experiences in similar areas looking at variables such as population density, average net income, inhabitants' education level, or other like parameters related to their consume patterns. These estimations allow to plan the entire networking investment and to adjust the required capital expenses needed to set up the operations. The right estimation of demand is a critical factor in any deployment because it lets balance the speed of the investment and its returns. Inaccurate estimations may compromise future network

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<sup>2</sup> We refer to traditional model as the integrated vertical operator that deploys the network to the final user.

<sup>3</sup> The demand estimation is always a critical issue in any deployment plan. From simple demand forecast based on socioeconomic data, more dynamic models try to engage demand on beforehand to reduce risk.

<sup>4</sup> The regulatory framework aims to enforce competition among carriers. The framework may change often creating more uncertainties that may affect the investment.

<sup>5</sup> Technology evolves and more efficient solutions may affect the overall investment. For example, mobile broadband may become a complement or a substitute for fixed broadband depending on the scenario.

upgrades and generate longer returns of the investment incurring in economic risks for the carrier.

Recently, new carriers -like Google Fiber- are changing the way in which the demand is estimated to achieve more accurate mechanisms (and less risky) to plan the overall investment. Google's fiber model is based on having a sufficient number of subscriptions engaged, which guarantees a minimum market share, before rolling out any fiber. Google's model starts launching a public contest where city councils and municipalities may apply and provide enough data and evidences of potential market as well as public facilities already in place to make the investment feasible. After the first contest in 2010 Google received data from over 1,100 communities and local governments, endorsed by more than 194,000 individuals<sup>6</sup>, all of them applying to get fiber deployed in their towns and cities. The first location selected was Kansas City, where Google got a detailed estimation of the broadband demand in all the neighborhoods and guarantying a minimum engagement among potential users. Having those levels of users pre-subscribed before starting the investment is a way to improve the demand forecast, reducing at the same time the risk of any future investment. After the first deployment, Google is expanding their operations in other states along the US and can be found in Kansas, Missouri, Texas and Utah. The Google's model also includes a strong commitment from the public administration to make the procurement related to any new deployment more agile and provide any existing telecom infrastructure, if available. These two elements make the whole project more challenging, less risky and also reduce potential delays derived from obtaining the rights of way for civil works or identifying the existing poles and ducts. The Google Fiber's model launched a competitive retail offer of 1Gbps in the US broadband at prices that are comparable to the regular broadband offer at 50 and 100Mbps from other big firms (Domingo & Lehr, 2013).

Other examples of network deployment with high user-involvement are the ones driven by groups of individuals –communities- organized in a cooperative way to deploy and share their own networks. Originally most of those networks come from the community grassroots wireless movements of the early 2000's, like Guifi.net in Catalonia, Freifunk in Germany or the Personal Telco Project in Oregon US. These communities build large networks, reaching sometimes several thousands of users, with their own contents and often sharing some gateways to reach the regular Internet. In some scenarios, these network deployments are also backed up by local authorities such as several Municipal Wi-Fi initiatives already implemented, see (Jassem, 2010) (Oliver, Zuidweg & Batikas, 2010) (Lehr, Sirbu, & Gillet, 2004).

As noted above, having users involved and engaged in the deployment of their own-shared infrastructure<sup>7</sup> is a first step towards a new way of rolling out networks where end-users are more active and even assuming part of the costs of the access network. In

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<sup>6</sup> News about the results were published after the contest at Teckcrunch (2010)

<sup>7</sup> The community of users can build by themselves (if they have the technology knowledge) or just contract a third party to do it. The model does not go into that details and assumes that each community finds the best solution to each particular case.

this paper we define user-aggregation as a community of end-users from the same neighborhood, building or location, that agree into create a private local infrastructure to share a single fixed high-speed broadband Internet service. The evolution of mobile broadband towards small cells is another example of how end-users are having a more active role when deploying networking infrastructure, empowering in-house small cells and allowing greater capacity and coverage under several scenarios (Oliver & Lehr, 2014). The motivations that move the end-users to share a common connection<sup>8</sup> are similar to the ones of grassroots wireless community movements (as stated above, they have close origins), see (Sadowski, 2014). In this paper we analyze urban scenarios where end-users are organized into residential buildings –coops or condominiums- as communities that are managing of a set of joint services and where a high-speed broadband service could be considered as an additional service of the whole community.

Examples of sharing a common Internet access already exist in university campuses, businesses organizations, offices, etc. In this paper we extend that model to the gross of the retail market, to explore how the change of model may impact on current investments. Then, the community needs to deploy a basic infrastructure<sup>9</sup>, typically a local area network, depending on the size of the community, as a private backhaul to reach the Internet connection. The management of the local access network relies on how the community decides to run the network. The options range from a complete shared model with no restrictions, to a more controlled and complex one including mechanisms to authenticate the users, balance traffic or restrict the individual data consumption per month. This article studies a model followed by users that aim to deploy their own network from their homes to the backbone network, hence the name Fiber From The Home – FFTH<sup>10</sup>, (Anderson, 1999).

The principle that makes the user-aggregation model feasible is known as statistical multiplexing, which provides a link utilization improvement (gain) when several uncorrelated user random flows merge over a shared trunk. Carriers use the statistical multiplexing gain to save costs in the high-capacity trunks by increasing its utilization (throughput). Thus, the rule of thumb used by carriers allows multiplexing several flows requiring less than a 5% of the sum up of the individual speeds. In the model discussed here, the community of users takes the advantage of statistical multiplexing by a smaller population but still with enough gain to become feasible. The details of how statistical multiplexing applies are presented in the next section.

This article analyzes the effect of the demand aggregation over the investment required to deploy a fiber network. Depending on the fraction of the market that aggregates demand, the overall deployment will need less fiber connections reducing the initial investment.

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<sup>8</sup> Some reasons are included as an example: tariffs, broadband availability, social techy movements against traditional providers or the simply need of services in community areas scarcely served.

<sup>9</sup> Private networks can be based on a different range of technologies that goes from Wi-Fi and cable to fiber or mobile extended coverage. Commonly implemented are the wireless solutions, as they tend to be cheaper and fast to be ready for their usage. In this article we account that users deploy a fiber-based solution.

Here, some questions arise: how is the overall investment – CapEx - affected when the demand is aggregated? The article also addresses some other related questions regarding how network providers are affected when a noticeable fraction of the market is aggregated, or how the current pricing may be adapted to the user-aggregation behavior?

The next section analyzes the statistical multiplexing as the main principle that makes the user-aggregation technically feasible, showing how empirical measurements in fiber broadband users allows us to derive the basic metrics that feed the whole model. Then, it continues with the description of the techno-economic model that analyzes the impact of user-aggregation over the overall investment and returns. The model is an adaptation of a model used in other techno-economic studies<sup>11</sup> and it evaluates the overall investment in a demand aggregation scenario. Finally, it shows the results obtained and continues with some concluding remarks.

## **2. Benefits of Statistical multiplexing model**

Operators are using statistical multiplexing metrics to design the trunks where customer's flows are converging in, see (Andersson, 2000) (Cao, Cleveland, Lin, & Sun, 2002). Each individual traffic flow follows a random pattern depending on the type of contents, the user habits and the type of access network used. When each of those individual flows, assumed to be independent, merge over the same trunk, the statistical properties tend to be markovian where traffic peaks are smoothed due to the overall utilization increased<sup>12</sup>. The statistical multiplexing accommodates a high number of customer's traffic flows over the same trunk at higher speed rate, but much lower than the sum up of all individual flow rates.

The drawback here consists of balancing the savings on the common trunk and the individual quality of service perceived by each customer. Carriers tend to use heuristic metrics and their own experience to balance the equation. Most carriers apply a rule based on selecting a variable value between 3% and 5% to seize the bandwidth needed for the common trunk depending on the number of users. Once the network is delivering customer's traffic, a continuous monitoring of the network traffic allows a finer measurement to adjust the speed needed depending on the quality of service offered to the users, the cost of the trunk, and traffic consumption pattern changes as well as the number of individual users' flows aggregated on each trunk.

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<sup>11</sup> The techno-economic model has been adapted from (Domingo, 2011) and (Domingo, Lehr, 2013) to group users and to adapt the fiber network design accordingly.

<sup>12</sup> Basically, it groups randomly packets sent from multiple users. These packets are grouped into the backbone network, the order would be something like this: first, it entries one packet from the first user, then a packet from a second user, now three packets from a third added to a new packet of the first, and it continues like this as long as the network is active. Individually it would have seemed tat the third user flow is sending a burst when he sent three packets, but it is smoothed when aggregated to all the traffic. Legacy networks controlled this through buffers that collected each flow and merged them to one flow at a known speed rate. Currently it is the overprovision of the backbone the first rule, as the less conversions than a packet suffers from optical to electrical the better, so old solutions like buffering are less and less common (Popescu & Constantinescu, 2011).

In this section we use empirical measurements obtained from one niche operator to compare the rule of thumb used and analyze how the statistical multiplexing may apply for smaller sets of users. The measurements were taken from a trunk collecting traffic from 572 fiber subscribers with a symmetric contracted service of 20/20 or 10/10 Mbps (download/upload).

For such number of subscribers, applying the 2-5% rule mentioned above and assuming that half of the customers contract one or another speed rate, the maximum speed contracted for the common trunk would be of 171.6Mbps and 429Mbps for 2% and 5% gain values, respectively. Without applying multiplexing gain the nominal speed rate would be of 8.6Gbps, which it would require a much more expensive trunk.

Observing the measures taken from the common trunk, shown in Fig. 1, it can be observed that the aggregation of flows from the 572 subscribers follows a regular daily pattern. Fig. 1 is also pointing out a busy hour<sup>13</sup> approximately between 20:00 and 21:00. The observed peaks of traffic are used to design the suitable network trunk capacity that must be close to 140Mbps to carry the maximum peak observed during that week. It is worth to notice that this maximum speed is close to the lower (171.6Mbps/2%) heuristic value first estimated for this trunk. The traffic pattern seems quite stationary during the whole week, highlighting Sunday's traffic (March the 23<sup>rd</sup>) where it reaches a slightly higher consumption compared to the rest of the week.

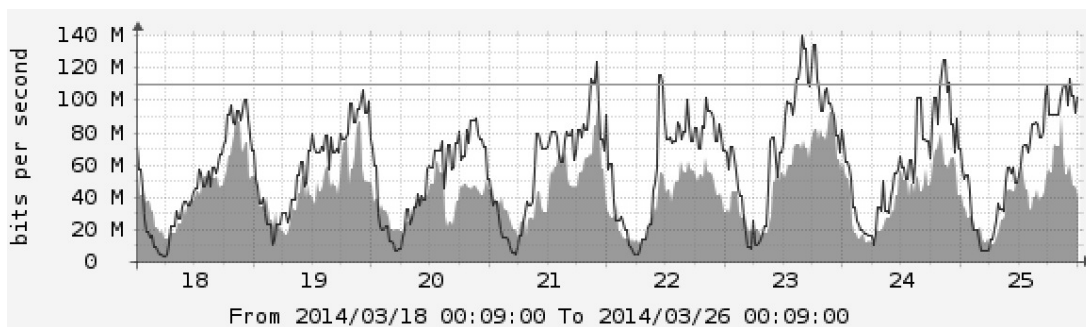
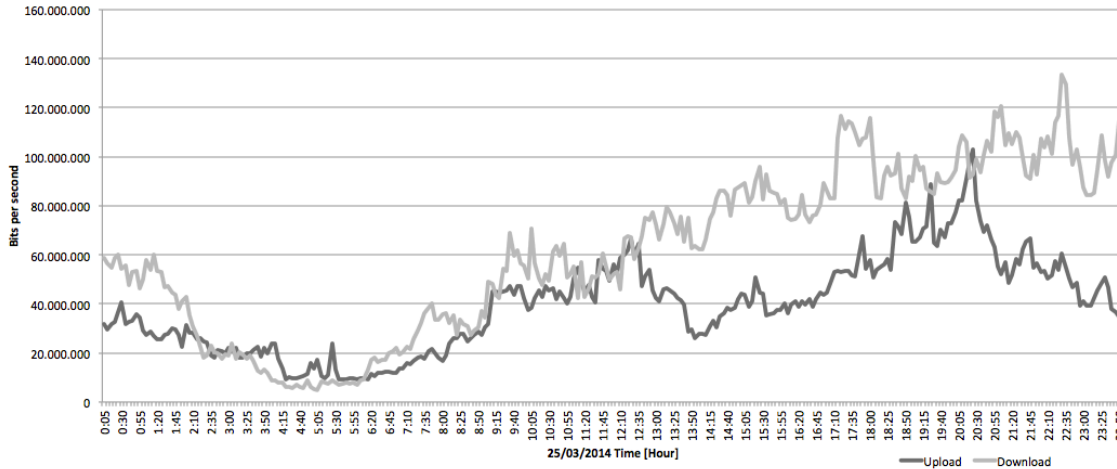


Fig. 1. Aggregated traffic for a 572 subscriptions single flows. Week from March 18th to 25th. Upload (full colored grey) and Download (dark line).

Fig. 2 shows a zoom of the aggregated measurements along one single day. Download and upload peak traffics are quite balanced during the whole day, being 133Mbps (at 22:30 approx.) and 102Mbps (at 20:15 approx.), respectively.

<sup>13</sup> The busy hour is defined as the sliding 60-minutes period of the day where the trunk is carrying more traffic.



**Fig. 2. March 25<sup>th</sup>, 2014, Upload (darker grey) and Download (light grey) measures taken every 5 minutes. Time is shown in the horizontal axis and bps in the vertical one**

When going into the details of the traffic flows it was observed that not all subscribers were active during the busy hour. A fraction of users just had the router on, generating a very light signaling traffic to keep the connection alive with no contribution with user-generated traffic on the common trunk. Other subscribers got the router device simply not plugged showing no traffic activity on the network. Finally, the rest of subscribers were effectively active generating most of the traffic carried out during the busy hour.

User measurements and observations allowed us to obtain averaged speed traffics per connection along the whole day and during the busy hour. **Table 1** shows that each active subscriber had an average usage speed along the day of 0.99/0.67Mbps (download/upload). The maximum peak speed per user reached a maximum value of 1.33/1.01 Mbps (download/upload) measured during the busy hour.

**Table 1 Averaged traffic per active user measured (March of 2014)**

	<b>Daily Average</b>	<b>Peak Rate</b>
<b>Upload</b>	0.67 Mbps	1.01 Mbps
<b>Download</b>	0.99 Mbps	1.33 Mbps
<b>Total</b>	1.66 Mbps	2.34 Mbps

Comparing those values with other measurements found in the literature such as the ones done in Japan in 2009 (Sato, Tokuhashi, Takeshita, Okamoto, & Yamanaka, 2013) we observe that they are lower because they included other narrowband technologies still dominant at that moment. Sato et al. measured average speeds of 43.2/29.9 Kbps and the peak rate 63.9/41.6 Kbps (download/upload) during the busy hour and they keep similar proportions as the values measured shown in **Table 1**.

The number of simultaneous active subscribers during the busy hour reached 118 from a total of 572 users, representing a fraction of 20.6% subscribers. Although national carriers work with larger figures, we have observed that noticeable gains may also apply in much smaller scenarios, like the user-aggregated model presented in this paper.



A recent report from the FCC measured the current speed rates offered by US ISPs to compare the real to the offered speeds, see (FCC, 2013). An interesting result shows how the average amount of data traffic consumed by users in each speed tier is positively correlated with the speed that each tier is offering. Then, higher speeds tiers means higher data consumption by the average user.

Next section presents the techno-economic model adapted to include a fraction of the demand in an aggregated way. The model uses the traffic measurements shown in this section to properly seize the connections that jointly serve groups of users.

### **3. Techno-economic model for dense urban areas**

The techno-economic model described in this article is based on an optical fiber infrastructure deployed in a dense populated urban area. The network infrastructure has been designed to provide Internet broadband connection to two differentiated market segments: individual households, and communities that aggregate users living in the same or neighboring buildings. The first segment is served in a traditional way, provisioning enough networking infrastructure to get the expected share of market in the long run. In our study we assume a 45% of the total market as a common target for new carriers that are second movers in a certain area. However, the second market segment aggregates a variable set of households behind one single Internet connection and allows an interesting simplification, and consequent reduction in cost, of the network design. Both segments are served using the same core network and are only different in the access part: no duplication of the infrastructure is done and all kind of customers are served under the same quality of service. The techno-economic model used here is an adaptation of a previous model that allowed a similar analysis for fiber investments in some areas of the EU and US (Domingo & Oliver, 2011) (Domingo & Lehr, 2013).

The user-aggregation of demand has already been successfully used in previous deployments. For example, the Swedish neutral operator Stokab followed a similar approach, where housing companies<sup>14</sup> agreed to implement and offer Internet access to their multi-dwelling units using fiber. This fact led to more adoption and spread of the open access network in Stockholm (Forzati & Mattsson, 2013). Hence, our model requires a higher degree of user involvement because in most cases a simple company does not own the entire building and the decision process and discussion whether to contract a common Internet connection among the landlords is be more complex. The model also assumes a hybrid scenario where traditional end-users with individual household connections may coexist in the same area with other users that aggregate themselves to share a single Internet access.

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<sup>14</sup> To agree with entire buildings is a must, as according to a Harvard study (JHCS, 2012). It is not unrealistic that citizens change their homes before a 15 years period of time. US inhabitants' migration average was set around 9 years in 2011 according to real state companies (NAR, 2012). In Europe young population set between 20 to 34 years old move from home after about 2,3 years<sup>14</sup> (GenCat, 2003). This helps to understand that all buildings are in need of fiber as they are one utility more for all this population that periodically migrates.

### ***Model assumptions***

The model is based in a high dense populated area and the figures are taken from the city of Barcelona. The results may be extrapolated to other urban areas with similar shape where the end-users may be grouped in buildings as we explain below. Then, we assume broadband end-users living in apartments that are congregated in the same building as a single community. Those communities, which often are constituted as legal entities, used to manage and share a set of common utilities and services joined by all members, such as utilities (gas/electricity/heat/water), gardener, swimming pool, elevator, doorman, or any other community service. According to the Spanish official data sources, buildings are classified into seven categories based on their size that is measured in number of households per building<sup>15</sup>. To make that grouping more manageable, we have simplified it in only three categories (see Table 2): type A, including buildings with an averaged number of 3 households that represent less than 10% of all buildings; type B buildings with an average of 11.9 households and are around one third of all city; and type C with an average number of 19 households per block and are the most popular in the city being 62% of all buildings.

**Table 2 Buildings classified according to the number of homes.**

<b>Building Type</b>	<b>Buildings in each category</b>	<b>Percentage over the total number of buildings</b>	<b>Average number of households</b>	<b>Total number of homes<sup>16</sup></b>
A	26,498	9%	3	73,084
B	19,808	29%	11.9	235,493
C	24,361	62%	19	503,467

### ***Pricing schemes and offers***

To compare the impact of user aggregation we will first use exactly the same pricing scheme whether the final user is a single household or a community. In both cases the service offered is exactly the same and consist of a basic Internet access at a maximum symmetric speed of 1Gbps. The techno-economic model only assumes the broadband Internet access and does not include any kind of content (TV, video on demand) neither voice nor mobile service. We assume that end-users may contract those services separately to the Internet access to third parties or service providers.

A second scenario foresees a pricing scheme split to differentiate single households from community access services. The latter will have a higher monthly fee that will be independent of the number of households engaged on each community. The way in which communities charge individual members is out of the scope of the paper, as it does not impact on the final results. In both cases the pricing schemes are established as an initial connection fee to cover the installation costs plus a monthly amount to cover the operational expenses and make the whole investment sustainable within fifteen years. To

<sup>15</sup> INE and IDESCAT are the official bureaus for statistics in Spain (INE, 2011) (IDESCAT, 2011)

<sup>16</sup> 812.044 homes compose the city of Barcelona (Barcelona City Council, 2010)

fix a monthly fee for communities we have used the statistics about the size of buildings in the area. Table 3 shows the average number of subscribers per type of building using the metrics presented in the previous section. The largest building category has an approximated average of four active users during the busy hour. To cover that scenario, we arbitrarily decide to set a monthly fee for communities four times the fee applied for single households. In the next section we will go back to those values to see the impact of prices over the whole investment and payback.

**Table 3 Number of active homes per building**

Model Category	Average number of homes	Average active subscribers (busy hour)
A	3	0.62
B	11.9	2.45
C	19	3.92

Table 4 summarizes the offers used to in the techno-economic model. In both models (A and B), there is an installation fee, different from households than communities. The household installation fee covers the costs incurred by the carrier when first providing the in-building fiber connection to reach the end-user premises. The installation fee may be charged to the customer or integrated as part of the contract depending how the carrier commercializes the service. The community installation fee will be afforded directly by the building owners to deploy the in-building infrastructure that lets share the connection. While type A offer keeps the same monthly fee of €32 for both types of customers, type B offer increases the community monthly fee up to €128 to charge for the same speed rate but including a higher utilization of the broadband connection based on Table 3 active subscribers. In that sense, type A offer will allow us to explore the impact of user-aggregation performance in a market where there is no differentiated pricing strategy. Type B offer explores how a simple but differentiated model that overcharges community connections may balance the economics of the whole investment by changing the payback and return periods.

**Table 4 Price per building and home included in the model**

Offer Type	Household Installation	Household monthly fee	Community installation	Community* monthly fee
A (Equal)	€ 221	€ 32	€ 209·n	€ 32
B (Differentiated)				€ 128

\* Regardless the size of the community, the fee is kept constant  
 “n” is the size of the community in number of households

### **Deployment speed and costs**

The deployment costs are inferred from (Domingo & Oliver, 2011) where all the infrastructure needed to deploy a fiber network, following the FTTB (*fiber-to-the-building*) model in a dense city is estimated in approximately €493. That cost does not include any additional in-building infrastructure. If the community contracts the service, the owners will afford the creation of that infrastructure (if it does not exist yet). For

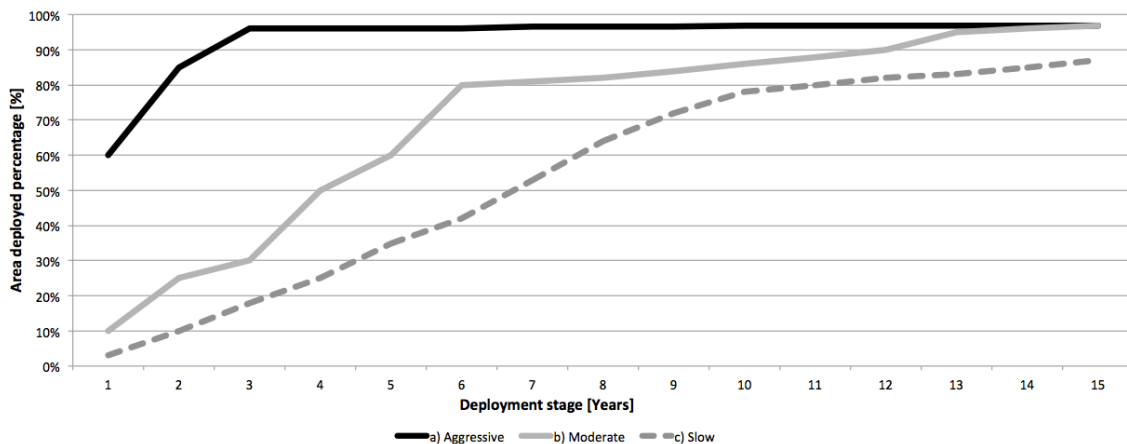
regular households, the carrier will be in charge of it. Table 5 summarizes the different costs associated to both segments targeted by the techno-economic model.

**Table 5** Main deployment model's variables

	Deployment costs			
	Individual Building	Individual Home	Community Building	Community Home
<b>Infrastructure (Once)</b>	€ 500	€ 120	€ 500	€ 70
<b>Equipment (Once)</b>	€ 300	€ 100	€ 500	€ 60
<b>Operational Expenditure (Yearly)</b>	-	€ 90	-	€ 45

\*Only available for private companies, and they offer dedicated services starting with different range of speed

The deployment model is addressed to cover a minimum 90% of the potential targeted market within 15 years. The model includes three different approaches to achieve that coverage (see Fig. 3): an aggressive deployment model that reaches 90% of the coverage before the end of the second year; a moderate deployment model that reaches 90% of the targeted market in twelve years; and a slow deployment model that takes over 15 years to reach that market.



**Fig. 3** Deployment models: aggressive, moderate and slow.

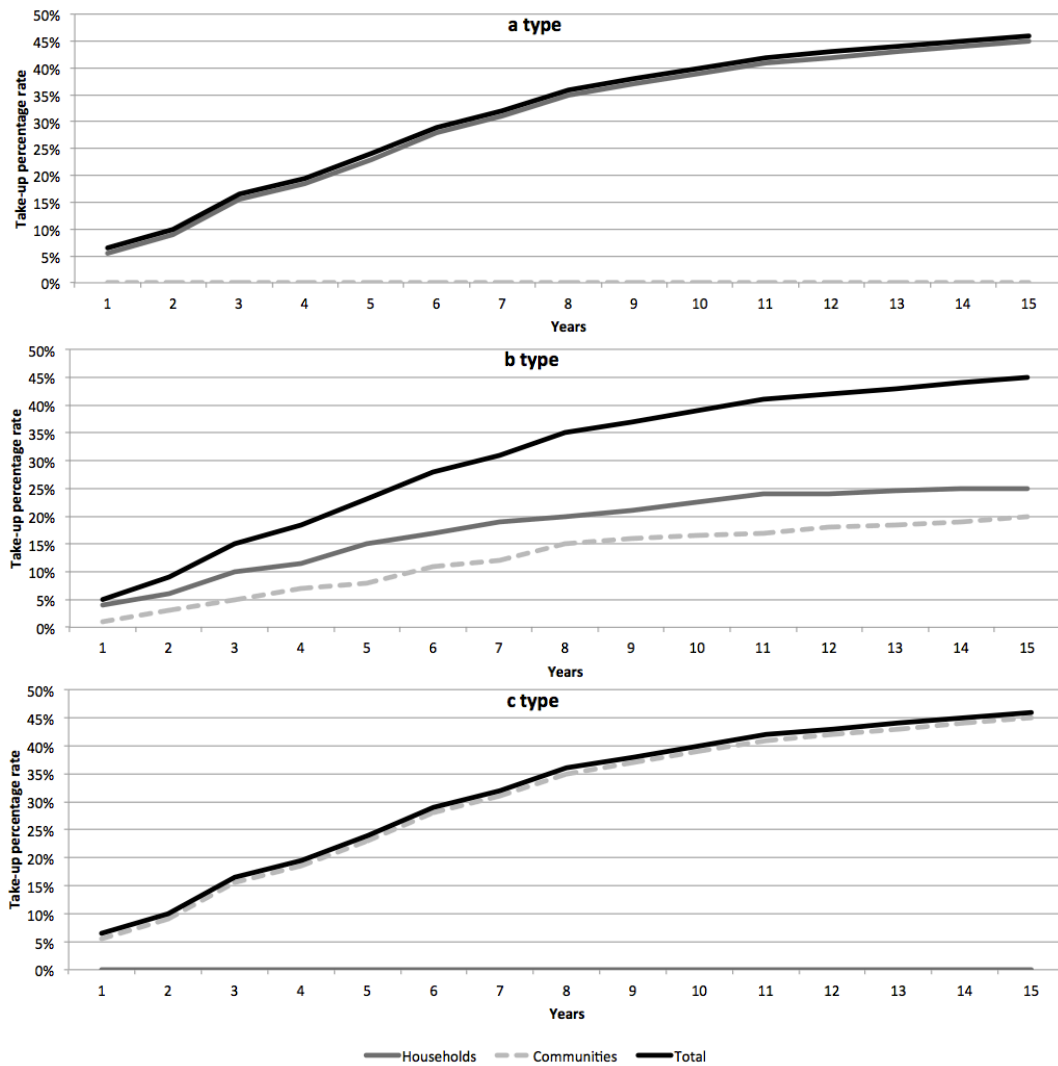
### *Take-up models*

In our initial discussion, demand estimation or take-up models are crucial to make fiber deployments sustainable and profitable. Like in the referenced techno-economic models, we will assume a common targeted market of 45%, reasonable for a second mover along the fifty-year investment. The way in which this final target is achieved slightly changes the revenues, and consequently may expose the viability of the whole project. All three

models of deployment considered (aggressive, moderate and slow) converge to cover a common goal of 90% of that market by the end of the project.

The model analyzed in this paper needs to differentiate between the take-up rates per targeted segment: households and communities. In both cases, the new entrant operator expects to reach the 45% of the whole market.

Similarly to the deployment speeds, we define three take-up rates to better characterize all scenarios and get comparable results. The first model (type a) only accounts for individual household with an initial take-up of 5% that increase in a quasi-linear way reaching 45% in year 15, with no aggregated demand in it. The second model (type b) is mixed and foresees the coexistence of individual households and aggregated demand at a share of 25% and 20%, respectively. Finally, the third model (type c) only has user-aggregated demand with no individual households at all. All three take-up models are shown in Fig. 4.



**Fig. 4 Take-up models used in the techno-economic model: type a, only individual demand; type b, hybrid; and type c, only aggregated take-up.**

While take-up cases a) and c) will allow to characterize extreme cases with the same profile of demand, the intermediate case b will provide a more likely scenario where both profiles of demand coexist in the same market. The next section analyzes the results obtained crossing all demand models and take-up scenarios to explore how the phenomenon of demand aggregation affects the overall investment.

#### 4. Results

The techno-economic model evaluates the investment targeting three main variables: the net present value (NVP), the return of investments (ROI) and the payback period (PB). The results, summarized in Table 6, show for each combination of deployment model, take-up scenario and pricing scheme: the numbers of years needed to achieve positive NVP, or to get a ROI over an interest rate of 10%, and the payback period.

These results first show that the aggregation of users is clearly affecting all three variables, becoming the whole investment non sustainable in some scenarios where there is no price differentiation, the demand side is entirely aggregated and the deployment models are both slow or moderate. Even when the deployment models are aggressive, the payback period reaches 10 years longer than in a scenario with no aggregation at all. Only the differentiation in price, setting a higher offer to communities can mitigate the effect of user-aggregation and keep the results close to 5 years, only one or two years over the traditional scenario. Henceforth we will use the traditional scenario as a reference to compare other results.

The mixed take-up scenario (type b)), that considers a mix of targeted demand with 25% of households and 20% of communities, is quite consistent reaching positive returns in no more than one year over the traditional scenario. Obviously, differentiation of pricing makes the investment less risky and all investment lengths become close.

Based on the model results, the aggressive model provides better ROI periods at equal take-up scenarios for the different deployment strategies. As mentioned above, price differentiation is a key element to keep the investment sustainable, especially when the user-aggregated demand increases its market share. That result shows again how the pricing scheme is a key variable to keep the whole investment controlled.

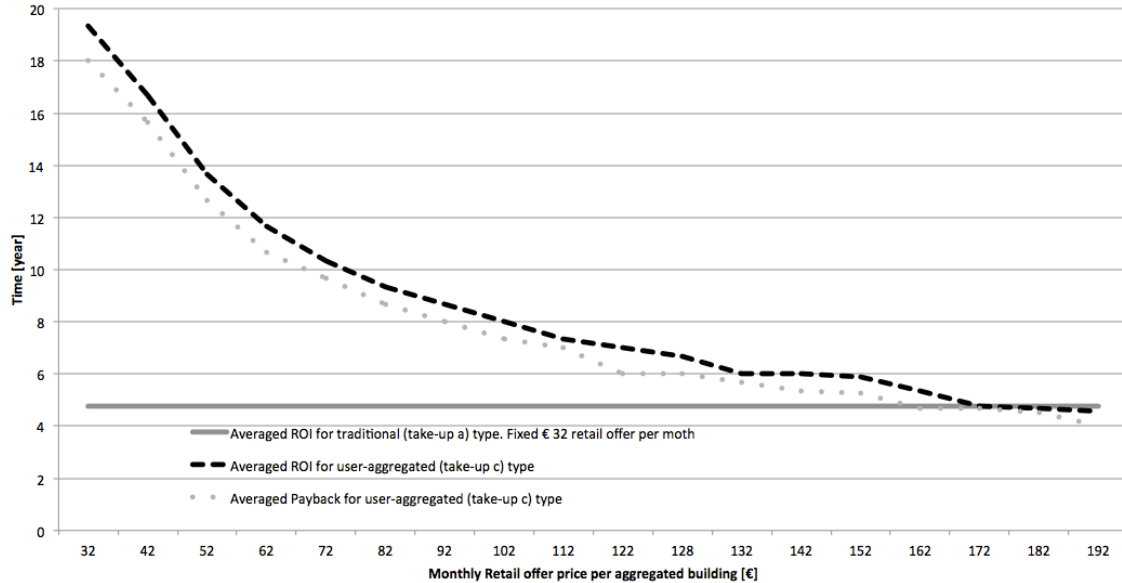
Comparing the overall project cost when covering the reference scenario (only single households) and a user-aggregated one (only communities), the model estimates both total costs of investments in €132.8M and €73.2M, respectively. The reduction in costs is noticeable, becoming a 45% less that represents an interesting strategy to lower the investment barrier for new entrants.

Finally, Fig. 5 depicts the dependence between the period needed to get the ROI over the interest rate and the monthly fee applied to the communities (we assume the single households fee constant). When no user-aggregated demand is considered (type a), the positive cash-flow period is constant and equal to five years. Using that value as reference for take-up c type (only communities) the price differentiation needs to be fixed close to €170/month.

**Table 6 Results shown in years for each model combinations. Results are also provided for three indicators: positive NPV, ROI>10%, and Payback year**

		Monthly retail offer price					
Time to achieve NVP > 0, ROI > 10% (in years)		Price scheme A (equal 32€/month)			Price scheme B (diff. 32€-128€/month)		
Deployment model	Take-up	NPV	ROI	PB	NPV	ROI	PB
Aggressive	Type a) only households	5	4	3	5	4	3
	Type b) Mixed	6	5	4	5	4	4
	Type c) only communities	15	14	13	6	5	5
Moderate	Type a)	6	4	4	6	4	4
	Type b)	7	6	5	6	5	5
	Type c)	NS	20	18	7	6	6
Slow	Type a)	6	5	4	6	5	4
	Type b)	7	6	5	6	5	5
	Type c)	NS	NS	19	7	7	6

NS: investment non-sustainable.



**Fig. 5 Pricing approach from a user-aggregated model to a traditional operator’s pricing model**

## **5. Conclusions and future steps**

A first conclusion is that there is a reduction by 45% of the initial investment for new entrants if the strategy is addressed to offer broadband services to communities instead of single households. Moving from single end-users to communities reduces both, the potential revenues but more relevant, almost one half of the initial costs of the total investment. In that sense, the strategy of user-aggregation may be used as an incentive to reduce investments barriers and promote competition in areas where the households are grouped in already existing communities such as buildings or residential neighborhoods.

The techno-economic analysis also shows how the user-aggregation heavily impacts on the broadband investment when no pricing differentiation is used. Although the scenarios selected consider extreme values for take-up, when the demand is aggregated the revenues are reduced and the sustainability of the investment takes up to three times longer than expected, or it may even compromise the whole project becoming unsustainable and never reaching the break even point.

The pricing offer that differentiates between individual and community users is an interesting variable that helps to turn the model sustainable by reducing investment risks. The ROI is more homogeneous among the different take-up predictions when the price is based on connection usage rather than peak speed rate. To get the similar payback lengths, the offer for communities must be from four to five times higher than the individual one.

More aggressive deployments that concentrate most of the investment during the first three years of deployment tend to provide shorter payback periods. This is because the aggressive deployments rapidly increase the coverage maximizing the existing demand already covered in most areas, which helps reaching higher number of customers that are translated into sooner profits.

Although user-aggregation has been often marginal in terms of market share, in urban scenarios with higher density of housing it seems relatively easy to deploy. Probably, only a new entrant may use that strategy to disrupt the market and gain a noticeable market share with less investment and in a relatively short time rather than following a more traditional approach. We are still in an undeveloped and rising broadband market, too reliant on traditional models, but the future of new fiber deployments is wide. Fiber technology is becoming mature and shows a high potential and versatile in offering flexible topologies to distribute almost unlimited capacity among customers. This paper is more exploratory than conclusive and tries to understand how future models for fiber deployment will disrupt the broadband market, especially when the role of the users becomes more active and challenges the traditional telecommunications models.

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