Future proof strategies towards fiber to the home

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Abstract

Telecom operators are currently offering high speed Internet services over copper as well as cable networks. Besides the traditional Internet services, more bandwidth consuming services such as IPTV are forcing telecom operators to upgrade their networks. This upgrade is happening in most Western countries at a much slower rate than expected. The final step of migrating to an all fiber (last mile) access network is one bridge too far for most operators. Nevertheless, FTTH is considered as the solution for access networks in the long run. In this paper we will analyse different technical, as well as future proof strategies for the rollout of FtTH, taking into account the current network situation, new competition regulation and cost efficiency. The different roles and actors are considered, and for each type of competition model, the value network is presented and analysed in the light of changing technological needs, economic and regulatory conditions.

Keywords: Fiber to the home, competition networks, value networks
1. Introduction

Broadband Internet is becoming a commodity product in the Western world. According to Point Topic (2008), Western Europe has the second largest population penetration rate for broadband Internet services, but the market is reaching its saturation point (2.58% growth last year). When technologies are considered, more than 84% of the subscribers are xDSL (digital subscriber lines, via copper access networks) customers, 14% make use of cable networks, and only 1.5% is connected via fiber. Concerning overall fiber to the home rollouts, Western Europe is lagging (3.37%) compared to the rest of the world. Asia, more specifically China, South Korea and Japan, is leading with a staggering 84% of all fiber access connections (34 million users).

Several actors are involved in the overall process of rolling out fiber to the home and the motives for each of these actors differ. Telecom operators try to postpone large network investments in the access network by exploiting their current infrastructure. Small upgrades are implemented to keep up with the current bandwidth demand, but these migrations tend to be short term solutions. At some point in time a full migration towards fiber to each customer will be required. A complete fiber access infrastructure must be rolled out, which is a multi-billion investment. Next to telecom operators, other actors are showing their interest to invest in new future proof telecom networks. Municipalities (or government initiatives) have been a driver in the past for rolling out communication networks. Other public or private actors, such as utility companies, have good strengths and opportunities to invest in such initiatives as a result of economies of scale, right of way, etc.

We describe in the next section the different fiber technologies and architectures, paying attention to the current situation for telecom operators. An important issue is the ability to open the access infrastructure to competitors. This can be offered at different layers in the OSI model. In section 3, the different roles considered in the rollout of fiber to the home, are discussed, and the relevant actors are presented. For each of the different open access models, we present in section 4 the value model and map the actors upon the different roles. A comparison is made between the different models, related to choice of technology, network architecture, access for competitors and economic viability. We end this paper with some conclusions.
2. Technical models

In this section, we present the different fiber to the home technologies and architectures, taking into account current network infrastructures for telecom operators. Furthermore we discuss the competitive character of these networks, in terms of open access possibilities.

2.1. FttH technologies and architectures

At this moment, two types of technologies are used for offering broadband services to the customer: copper based digital subscriber lines (xDSL) and hybrid fiber coax (HFC) networks. In both cases, fiber has already been installed in the core and metro network, but the last part towards the customer is still copper or coax cable. Service offering (in terms of bandwidth) over copper networks (xDSL) is related to the length of the ‘last mile’ copper to the customer. For an ADSL service, this range is in the order of a few kilometer, for VDSL, this is limited to max 1.5km (for VDSL2+ about 300 meter) (De Marchis, 2003). In HFC networks, customers are connected to a service area (SA), where bandwidth is shared amongst the users. Decreasing the size of this SA is required for offering new technologies (e.g. DOCSIS 3.0) (Lanno et al, 2008).

When considering the rollout of a FttH network, a choice must be made between two categories of fiber networks, either passive or active, and the considered network topology, either point-to-multipoint (P2MP) or point-to-point (P2P). In a P2P topology, there are again two possible architectures: home run fiber and active star. In a home run fiber architecture, each user is connected by one dedicated fiber (P2P) to the CO. In case of an active star architecture, a switch or router is installed between the CO and the user, and from this point on, a dedicated fiber reaches each user. P2MP topologies are typically referred to as passive optical networks (PON), mainly deployed as a passive star or tree, where the access fiber is typically shared by 16 to 128 users. Regardless of the used architecture, in the central office (CO) the fiber lines of the users are terminated and connected to the different Internet service providers. From the CO, feeder cables with fibers run into ducts, to one or more intermediate flexibility points (FP) where a split is made, either in sub-cables with fibers (in case of home run), either the fibers are terminated on active equipment (active star) or the fibers are physically split and connected via a splitter upon a new fiber structure (PON). Figure 1 shows the three types of architectures.

Telecom operators tend to opt for PON networks, which is in line with their current network infrastructure (either xDSL or HFC). It is also difficult to give access to other operators, which is for a
telecom operator also an advantage (protectionism). In case of municipality networks, an active network, more specifically home run architecture, is chosen as most promising solution. The investment cost is slightly higher than PON, but it permits more competition possibilities. (Lannoo et al., 2008)

![Comparison of different FttH architectures](image)

**Figure 1: Comparison of different FttH architectures**

### 2.2. Competition models

Several levels of competition can be defined. Banerjee and Sirbu (2003) have outlined the models for competition in fiber to the home. We will further elaborate their subdivision, which is based on the OSI Reference Model (Zimmermann, 1980). An overview of our competition models can be seen in Figure 2.

![Overview of the competition models](image)

**Figure 2: Overview of the competition models**

#### 2.2.1. Physical infrastructure based competition

The "physical infrastructure based competition" model is situated at the lowest layer of the network, and is further split up into three models: trench, duct or fiber. The ‘trench’ level comprises the current infrastructure competition model, where every telecom operator owns a network in separate trenches e.g. in Belgium, the former incumbent Belgacom has a fully buried network, contrary to Telenet, the cable operator, which network runs on the facades of the houses. The ‘duct’ level of competition consists of the rollout of multiple networks in the same trench. This could impact the viability of the business case as in a buried FttH solution for instance, the trenching costs comprises over more than 50% of the overall rollout costs (Casier et al., 2008). The costs can be split over the different network owners, depending on
the actors e.g. the rollout could be geared to other utility works such as road works, sewage, electricity, etc. In case a shared duct infrastructure is offered by one actor e.g. a utility company or municipality, telecom operators can incrementally roll out their networks by blowing fiber into the ducts, each having the opportunity of choosing their fiber architecture, rollout speed and area. The ducts can be rented on a long term contract. This is called competition at the ‘fiber’.

For the physical level, all fiber architectures and technologies could be used.

2.2.2. Data link layer based (UNE) competition

“Data link layer based (Unbundled Network Elements) competition” model allows competition on the technology (e.g. Ethernet, ATM) to be used over the physical medium. The unbundled network element could either be the fiber or wavelength. In a PON network topology, the fibers are split up in several flexibility points to the different users, thus the same data link architecture must be used. This problem could be solved by using VLANs.

Competition at wavelength level is optional, as not all technical solutions are able to offer this type of competition. Two models can be considered for opening the network: wavelength per service provider or per subscriber. In the first model, each service provider rents a wavelength of the communal owned fiber, and offers services to their customers. This competition model can easily be managed in home run and WDM-PON architecture. On each wavelength, a different data link technology can be chosen. In the other model, each customer can be served on a different wavelength. The number of potential customers served depends on the number of wavelengths, which is the case for a WDM-PON architecture where fibers are split in the access network over several customers. In case of a home run fiber architecture, each fiber can directly be connected to the service provider in the central office. Data link layer based competition (UNE is wavelength) is not applicable for an active star topology.

2.2.3. Network layer based competition

The “network layer based” model of competition (or “open access based model”) can be applied for all technologies and topologies, and is situated at the IP level. The user can choose between several telecom providers offering different packages of services. This level of competition resembles bitstream access in the copper access network (in this case via IP or ATM).
2.2.4. Application layer based competition

The highest layer is competition at the “application layer” where there is a wholesale agreement with one provider, who has ownership or leases the complete infrastructure and offers connectivity. The customers can than separately close deals with different service providers e.g. video providers, VoIP, Internet, etc.

3. Value network

This part describes the different roles that must be fulfilled in order to come to a business model for a fiber to the home rollout, as well as the main actors involved.

3.1. Roles

3.1.1. PEST framework

The PEST framework (Political, Economic, Social and Technological) was designed to model the external environmental influences on the business framework. This framework will influence the rollout parameters for a fiber to home network. We based our analysis on Friend and Zehle (2004), where a PEST analysis was made for broadband data access, related to the migration from dial-up access towards faster xDSL and cable networks.

The political factors are controlled either on European, national or local level. Competition and investment regulation will determine which networks are considered (different regulation for copper and cable networks), whether operators want to investment in new network infrastructure, at which level the network infrastructure must be opened for competition (cf. Section 2.2), cost based allocation schemes applied by the national regulatory agency (NRA) for determining interconnection and local loop unbundling (LLU) tariffs, universal service provisioning, net neutrality, etc.

Economic factors include degree of competition, economic growth, loan conditions at the financial markets, inflation, equipment costs, market based tariffs for interconnection and LLU, etc.

Social and demographic factors determine market potential, Internet penetration, willingness to pay for telecommunication services, adoption rate for new technologies and services, etc.

The technological factor will influence the decision which technology could be used, which options there are for incremental updates in the network, possibilities of opening up the network, killer applications, security, combinations with wireless technologies, etc.
3.1.2. Fiber to the home business roles

The business roles in a FTH network rollout are based on the cost decomposition model in Casier, et al. (2008). Four major steps are specified: plan, deploy, operations and service provisioning.

The planning phase is subdivided in four roles. The first role focuses on the right of way (RoW). Several competent authorities can grant (or deny) RoW to install facilities on, over or under private or public property (Kittel, Ruhle, Schuster, 2008). The network planning determines which part of the market to focus on (potential target groups, areas to be included, number of services to offer) and customer forecast, and the technical design including choice of technology, topology and architecture. An important factor to be taken into account is the current situation and infrastructure as new incremental investments could furthermore expand the current network. The next step is determining a (practical) rollout planning, based on the previous roles and taken into account RoW, local regulation, administration and other utility works, but also available man power for executing all works. The final planning step is to find funding for the project.

The deployment phase includes the rollout of the outside plant (OP) and inside plant (IP). The outside plant includes trenching, installing the duct and fiber infrastructure, flexibility points (man holes, street cabinets) and other passive (e.g. splitters in a PON network) or active equipment. The inside plant consists of all equipment and installation required in the central office (CO) (e.g. OLT cards, racks).

The operational phase consists of network operations, including operations, administration and maintenance (OA&M) and continuous costs (floorspace and energy for power and cooling) and customer relationship management (CRM).

The service provisioning phase consists of physical connection of the fiber to the in-house network, and disconnection from the old network, services provisioning (connectivity) and content delivery.

3.1.3. Relations between roles

The complete model is shown in Figure 3, where the different roles (white rectangles) are presented, related to the different phases (the vertical blocks). Horizontally the OSI layer structure is shown (note that the optical level (O) corresponds to the physical layer at the OSI model). This model will be used in section 4.2 for analysing the most future proof value model.

Note that the PEST factors have direct impact on the planning phase. The political factors regulate RoW, network planning (e.g. whether networks should be opened for competition or not will impact the choice of technology, universal service provisioning, etc.) and the financial rules for network investments.
(e.g. related to governmental funding for NGA networks). The economic factors determine the size of the investment (which are the viable areas to rollout) and related to loan conditions. Social factors will affect the rate of adoption, and the technological factors will determine technology choice, network architecture and topology, thus the future proof level of the network investment.

![Fig 3](image)

**Figure 3: Overview of the different roles in the rollout of a fiber to the home network**

### 3.2. Actors

The main actors involved in the rollout of a fiber to the home project are discussed in this section. The actors analysed in this study are governments, telecom operators, utility companies, service and content providers, and customers. Vendors have also a large impact on the technical as well as economic impact of a fiber to the home rollout, but are not considered as they are external to the model.

#### 3.2.1. Governments

The *European Commission* introduced regulation in regard to ensure liberalisation and competition in the telecommunication market. Viviane Reding, commissioner for information society and media, has proposed the review of the telecoms regulatory framework. A new agency BERT (Body of European Regulators on Telecom) will be formed, which will be an expert advisory body. Its goal is “to promote fair competition and high-quality services across the EU by ensuring that national regulators use similar tools when faced with similar market situations” (European Parliament, 2008). The number of relevant telecom markets for competition, where actors with significant market power could arise, is also reduced from 18 to 7. The most relevant markets are wholesale for (physical) network infrastructure access (including shared or fully unbundled access) at a fixed location and wholesale broadband access (European Commission, 2007). The significant market share by the former incumbent in the telecom
market is still noticeable (IDATE, 2008). But some problems arise for the rollout of fiber access networks. Due to the new Telecom Package proposal, network operators might be forced by the NRA to functional separate the infrastructure from the service provisioning. A decision regarding regulation to opening fiber access networks to other operators is still pending. This can negatively influence the viability of the business case and might defer investment decisions in FttH. Europe is already lagging behind North America and Asia in the number of connected customers, as pointed out earlier. The European Commission is also reluctant towards local or national government funding. Another issue is the discrepancy in regulation between copper and cable networks regarding to open access. Clear communication about future regulation should clarify a lot of uncertainties and might lead to new network investments.

*National governments* have their interest in ensuring a decent network infrastructure for everyone. Therefore measures (sometimes imposed by European institutions) have been taken by the national regulator. One of these measures is ensuring universal service provisioning obliged to be offered by the former incumbent. As this is only for voice services, it is not clear how this will be arranged when this service is offered over fiber access networks (VoIP in stead of telephony over PSTN network). Another issue on the agenda is closing the digital gap. Therefore the national government could make sure a good framework for telecom investments is foreseen, as well as the necessary clarity regarding future regulation. Sometimes subsidies are available for dedicated projects such as bridging the digital gap.

*Local governments or municipalities* have the same purposes as national governments (good telecom infrastructure as well as closing the digital gap), but are more focused on the practicalities regarding the rollout of the networks e.g. in line with other utility works, social perception, connection for every inhabitant, etc. The rollout of a new access network could lead to major advantages for the municipality in the form of direct and indirect effects: new e-services (improvement and cost reduction compared to the current processes), image building, attraction of more inhabitants, more investments, etc, which could all enhance the viability of the business model. Therefore municipalities could facilitate these practicalities (administration, forcing faster rollouts by lining it up with other utility works, aerial or façade rollout), or even invest in network infrastructure. The latter issue is closely followed by the European Commission and could lead to some problems in opening it up to the public. An investigation was executed for the CityNet case in Amsterdam, where the city financially participated in a consortium for the rollout of the physical infrastructure of a FttH network (European Union, 2007).
3.2.2. *Telecom operators*

The Incumbent Local Exchange Carrier (ILEC) will have to migrate in the future to more fiber in the access network as replacement of the current copper infrastructure to offer higher bandwidth to its customers. Migration towards ADSL and VDSL standards will only be sufficient for the upcoming years. Fiber access networks will be required, but the main problem is the high investment cost, and what to do with the current access infrastructure? Will the fiber network be furthermore built out of the current network, or will a more optimized greenfield solution be considered? Another problem is regulation for incumbents due to significant market power, and the potential problems regarding direct opening of the new network infrastructure.

On the other hand, we have the Competitive Local Exchange Carriers (CLEC), where a difference is made between the cable operators and operators that lease lines via LLU regulation from the ILEC. The cable operators are also trying to extend the potential of their Hybrid Coax Fiber (HFC) network. Upgrading to DOCSIS 3.0 allows to reach bandwidths up to 120 Mbps, but requires smaller service areas. Even higher bandwidths could be reached in the future with new to be deployed DOCSIS standards (Bernstein and Gorshe, 2008) but as this will be based on the PON topology, a high investment costs for replacing the access network will be required. The other CLEC operators in this case will not be able to build out their own network as they currently lease the access infrastructure of the ILEC. In case the ILEC would upgrade its network towards FTTH, the operators will have to migrate. Depending on the tariff (based on real costs or adjusted with a margin) asked by the ILEC for using the access network, competition with CLEC (LLU) and cable operators will take place. For sure the network owner wants to recover the costs of the investments. The margin for service provisioning by these CLEC's will be limited in case they still want to compete with the ILEC. Extra costs will also be involved for upgrading their core network and equipment in the point-of-presence (POP).

3.2.3. *Utility companies*

Other actors that could be involved in the rollout of fiber are utility companies (gas, electricity, sewer, roads) as they have already RoW for the rollout and maintenance of their own networks. The cost of adding additional ducts and/or fiber to their trenches is minimal, as digging costs equals the largest cost. Several examples can be mentioned where ducts (e.g. Wienstrom in Vienna, Austria) or fiber (e.g. Mälarenergi in Västerås, Sweden) are offered by utility companies. Main problems could be the monopolistic position by one utility actor for multiple utility infrastructures (e.g. Wienstrom). In most
cases the telecom infrastructure is rented to service operators, thus vertical separation of network infrastructure and service provisioning is applied.

3.2.4. Service and content providers

The service and content providers will play an important role for stimulating competition in the broadband telecom market. As the European Commission is stimulating vertical separation between network and service provisioning, multiple players could participate in offering competitive services, whether in bundles or per application.

3.2.5. Customers

Customers (in this case inhabitants and SMEs) are asking more and more bandwidth due to more demanding services such as IPTV, Internet access, online storage, etc. Price/quality (in most cases bandwidth and IPTV) is an important factor for customers to choose their service provider. Competition can enhance this factor. The main problem is that the market in most countries is a duopoly or oligopoly situation (mostly ILEC and CLEC cable operator), where competition from other CLECs (mostly via LLU) is limited (IDATE, 2008).

4. Value networks for competition models

In this part of the paper, we will analyse the different models for open access networks, proposed in section 2.2, and relate the potential strategies of the different actors on the value network and the options they have regarding the speeding up of the rollout of FtTH networks. This work is based on a previous cost based analysis (Van Oteghem et al., 2008).

4.1. Focus

Each actor, described in section 3.2, could influence the rollout of fiber access networks. Different steps of influence by governments can be taken, each with more contribution: broadband user, rule-maker, financier and infrastructure developer (Gillett, Lehr and Osorio, 2004).

In a first step (broadband user), interested customers for a FtTH service could be gathered, either by the government, or by local action committees, and as such stimulate infrastructure developers to invest in new networks. This way service adoption for a new network can be increased (e.g. in the form of pre-registration for inhabitants) and other actors of interest (e.g. government for eServices, industry for intra networks, etc.) could be convinced, thus will improve the viability of the business case.
In the second participation step (rule-maker), actors can play a facilitating role. Governments could for instance optimize and alter administration processes in order to enable an easier infrastructure rollout e.g. less time needed for building permits or a better planning lining up these construction phases in relation with other utility projects such as road or sewer works.

The third step (financier) is supporting financially broadband infrastructure projects. This can be in different forms: funding own (utility) infrastructure (cost advantage for ILEC and CLECs), tax reductions, subsidies per customer, etc.

The final step (infrastructure developer) contains financial as well as operational involvement from the actor in this project. This relates to controlling the project, placing infrastructure at disposal of the operator of the network, help building and maintaining the network, service provisioning, etc.

Other parties as well can differentiate their focus, depending on the situation. An example is that customers could finance a part of the access network. An example of this model is occurring in Sweden, where building owners have to pay for their FttH connection (Van der Woud, 2007).

4.2. Competition models

Some actors are independent from the type of competition model and will only be discussed in this section (not mentioned in the following figures). The European Commission can influence the political (e.g. change in Telecom Package) and economic (e.g. subsidies for broadband network investments, such as in Greece) framework which will impact competition in the telecom market and investments in next generation access (NGA) networks. The same influences can be attached to national (more specifically NRA measures) and local governments. The latter has also an impact on the social framework. Widely, local municipalities are the competent authorities dealing with granting RoW and the issuing of building permits. With regard to co-location and sharing of the RoW (passive infrastructure such as trenches, ducts, fibers, street cabinets, etc.), competences are shared with the national regulation authorities (Kittl, Ruhle, Schuster, 2008). Some providers have already a RoW, required for operating necessary repair processes that need immediate interventions (e.g. water or gas problems), or for connecting customers to their networks (e.g. incumbent telecom or cable operators).
4.2.1. Physical infrastructure based competition

a. Physical infrastructure based competition (trench)

Every physical infrastructure provider (PIP), in this case coincides with the network infrastructure provider (NIP) and service provider (SP), will rollout its own network infrastructure (Figure 4). The RoW permission is granted to the PIPs by the local government to rollout new infrastructure. All infrastructure roles are executed by the PIPs (physical, optical and data link layer), thus these actors will use their own trenches and fiber infrastructure, flexibility points and COs with indoor equipment.

In this model there is only one scenario for stimulating investments. The local government will have to focus on collecting broadband users and rule making decisions, thus facilitating the processes for network rollout (e.g. better and faster administration). This is the pure model of infrastructure competition known today (ILEC versus cable operator networks). Multiple networks are rolled out next to each other, leading to surplus costs for each PIP (e.g. no communal trenching) and extra inconvenience for customers/inhabitants (e.g. multiple road works in short term). Competition is only guaranteed on the physical level, thus only the big players will be able to rollout such an infrastructure. In France, the city of Paris has lowered its tariffs for using its sewage network for rolling out new infrastructure (Van der Woude, 2007)

![Diagram of Value network for physical infrastructure based competition (trench)](image)

b. Physical infrastructure based competition (duct)

In this model (Figure 5) a new infrastructure provider (PIP) will be in charge of network and rollout planning, operations, as well as financing the trenching works. The NIPs roll out its own duct and fiber network, as well as equipment for optical and data network layer. They will also take the roles of SP.
Each customer can choose its provider (NIP/SP) and will be connected to its network. As in previous model this leads to duplicated network architectures, and excessive costs. Different facilitating network rollout scenarios are possible:

- Local governments will apply a facilitating rule-making focus, so that PIP and NIP are stimulated to rollout. This model is valid for all physical infrastructure based competition models.
- Utility companies could roll out their own networks (e.g. new water or gas pipes). Other operators could make use of the same trenches (probably at a different depth) and costs could be allocated based on a predefined scheme, sharing communal costs between players.
- Local governments can invest in infrastructure development by financing and operating the trenching works. The city itself could finance the road works, and give telecom operators the chance of cost efficiently rollout duct/fiber infrastructure.

![Diagram](image)

**Figure 5: Value network for physical infrastructure based competition (duct)**

c. Physical infrastructure based competition (fiber)

The next variant of the model, competition at fiber level (Figure 6), includes for the PIP in the outside plant trenching as well as providing duct infrastructure. The NIPs have the option to choose its fiber architecture and data link technology, but the topology of the duct network, as well as the location of the flexibility points (possibly also the location of the CO) is fixed. They will also take up the role of SP.
Local governments (or subsidiary e.g. local utility company) could invest in a duct infrastructure. These ducts can then be leased or sold to NIPs. The NIPs will have to invest in their own fiber and equipment infrastructure, having the possibility to choose the technology and architecture, but not the topology. The FPs and COs of the PIP will have to be used for equipment storing. In France for example, all operators could make use of the duct infrastructure network of France Telecom (FT). In this case, FT is PIP as well as NIP, and other telecom infrastructure providers (NIP) are rolling out their network making use of the PIP’s duct network (Fournier, 2007).

Multiple networks could be rolled out incrementally next to each other, leaving the NIPs the choice of choosing their rollout areas. Fiber will have to be blown into the ducts. A disadvantage of this model is churn cost. Each customer will have to be migrated physically from one network to another, leading to new fiber blowing, connection cost and administration.

![Diagram](image)

Figure 6: Value network for physical infrastructure based competition (fiber)

4.2.2. Data link layer based (UNE) competition

a. Data link layer based competition (UNE = fiber)

This model (Figure 7) is based on the full lease of the fiber infrastructure. One actor (PIP) owns and operates the fiber network, without investing in outside or inside plant equipment. One or more NIPs have the opportunity to lease dark fibers and install their own data link layer equipment. Mainly the case for these types of networks is a wholesale deal by one NIP with the PIP to offer services. Different facilitating network rollout scenarios are possible:
• Local governments could participate in a PIP consortium, just helping to finance the project. Amsterdam applied the same type of model, where Glasvezelnet Amsterdam BV is PIP, a wholesale provider was chosen as NIP via a tender procedure and multiple service and application providers can offer existing (TV, Internet, telephony) as well as new services to customers.

• Another form of local participation is through subsidiaries e.g. utility companies partly or fully owned by the local government.

The main advantage of this model is that passive infrastructure (PIP) is nicely separated from the active equipment (NIP) and service provisioning, which is in line with potential new European legislation models. The outside plant equipment could also be installed by the PIP as well in case the PIP determines the network technology e.g. installation of splitters for PON in stead of active equipment in the flexibility points.

![Figure 7: Value network for data link layer based competition (UNE = fiber)](image)

b. Data link layer based competition (UNE = wavelength)

In this model (Figure 8), the PIP will take care of outside plant, including the physical connection of the customer. The NIP will lease wavelengths from the PIP and installs data link equipment in the central office. Two sub-models were proposed in section 2.2: wavelength per service provider (where NIP will coincide with SP) or wavelength per customer. In both cases the PIP must ensure that outside plant
equipment as well as inside plant equipment is capable of splitting the different wavelengths, without causing interference. On each wavelength, the NIP can then choose its own data link layer technology. This model will probably only be used in case a telecom operator has rolled out a PON network, and will be forced to open up its network to other operators. The installation of WDM-PON can then be a (costly) solution. This model will not be considered when a new fiber network infrastructure is designed, certainly not with new European regulation on the move.

This model has as major disadvantage that equipment for splitting of wavelengths (WDM-PON) is still very expensive and thus more an option towards the future.

![Network Diagram](image)

Figure 8: Value network for data link layer based competition (UNE = wavelength)

### 4.2.3. Network layer based (open access based) competition

This model (Figure 9) closely resembles the bitstream access models for copper networks. The PIP and NIP are one actor, choosing the technology, topology, architecture and data link technology. Service and application providers could offer their services over the IP network of the PIP, without installing equipment in the CO. Customers can easily choose their SP. Different scenarios are possible:

- In case of the rollout of a new network, the local government can participate through their subsidiaries who own or are willing to invest in telecom infrastructure e.g. utility companies.

The full network (physical, optical and data link layer) up to layer 3 is provided by the PIP/TIP.
Open access is provided for SPs via bitstream access. In Vienna, the utility company Wienstrom (PIP in this case) had already a fiber infrastructure but needed data link equipment (Ethernet) for connecting customers via their passive infrastructure. An open access network is offered, where Bizznet (full ownership of Wienstrom) connects customers to the fiber network, offers services as well, but also lets other SPs to the network.

- This model can also be applied when a PIP/NIP has already rolled out a network and offers services over this network. In case it has to be opened for competition, this will be the easiest solution.

This competition model is always applicable, independent of the choice of technologies, topologies as architectures, and has a low entry level for competitors to make use of the infrastructure and offer services to the customers.

![Diagram](image)

**Figure 9: Value network for network layer based competition**

### 4.2.4. Application layer based competition

The final model (Figure 10) situates itself on the highest layer of the OSI model, the application layer. In this case, there is only one actor (or consortium) involved in the offering of services to the customers. This actor takes the roles of PIP, NIP and SP, meaning that a monopoly is formed. The customer is obliged to agree on the terms of the actor for connecting to this access network. A choice can made between application providers e.g. different VoIP provider, TV or HD providers, etc. This model resembles physical layer based competition at RoW level, except there is only one physical infrastructure
available, and that PIP/NIP is also SP. The customer can only choose application providers for its services. In most cases this is also arranged through the operator. Examples of this type of network are NetCologne (in Cologne, Germany) and Fastweb (in Milan, Italy), both (initial) local government initiatives.

Figure 10: Value network for application layer competition

5. Actor influence on competition models

This part focuses on the actor influence on the competition models, presented in the previous section, and how real options analysis could capture uncertainties in the business case for fiber access rollouts.

5.1. Comparison of the competition models

In Table 1, an overview is given of the different competition models for fiber to the home access networks, with technologies to be used, entry barrier level for competition, and main (dis)advantages.

<table>
<thead>
<tr>
<th>Competition model</th>
<th>Technologies and architectures</th>
<th>Entry barrier for competition</th>
<th>Main advantages/disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical layer</td>
<td>Home run, Active Star, PON, WDM-PON</td>
<td>High</td>
<td>Upgrade from current network situation possible (+)</td>
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<td></td>
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<td>Able to choose technology and network topology (+)</td>
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<td></td>
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<td></td>
<td>High investment costs for all parties (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multiple fiber networks(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Switching SP for customers difficult and expensive (-)</td>
</tr>
</tbody>
</table>
| Data link layer | Home run WDM-PON | Medium | **UNE = fiber**  
Full vertical separation of physical and active infrastructure (+)  
Limited choice of technologies to be used (-)  
Mostly one NIP responsible (wholesale), access to the customers via network layer competition (bitstream access) (+)  
\[UNE = \text{wavelength}\]  
Difficult to implement (-)  
Expensive WDM equipment required (-) |
|-----------------|-----------------|--------|-----------------|
| Network layer   | Home run Active Star PON WDM-PON | Low | Single physical and network infrastructure (+)  
All technologies and architectures can be used (+)  
Easy solution for SP competition (+)  
Increasing level of protectionism (+)  
Lock-in situation (-) |
| Application layer | Home run Active Star PON WDM-PON | Low | One PIP/NIP/SP, thus monopoly situation (-)  
Increasing level of protectionism (-)  
Lock-in situation (-) |

For all competition models, public bodies such as European Commission or NRA could facilitate the rollout of next generation access networks by stating clearly the future strategies concerning telecommunication regulation and investments in telecom by governmental institutions.

The physical infrastructure layer competition model is interesting for ILEC and CLEC (cable operators) as they can reuse current network infrastructure in the rollout of fiber directly to the user (Katz, 2008). Each PIP can choose its network technology, architecture and topology (in case of ‘trench’ model). The use of a communal CO is required from ‘fiber’ infrastructure competition on (due to fixed duct infrastructure), where each user can blow its fibers in the leased ducts. As customers are connected to the network of one PIP, switching SP (and thus PIP) is difficult (new fiber connection, lots of administration and operational processes) and thus expensive.

At data link layer, the passive infrastructure is separated from the active infrastructure. The PIP is owner of the fiber network, and mostly a wholesale deal is signed. Network topology is fixed, network architecture and technology could be chosen when data link layer competition is applied to the full fiber network (installation of outside plant equipment by the NIP). Different technologies could be used next to each other by different NIPs e.g. PON network next to an active star. This is not the case for wavelength competition as inside equipment is required (installed by the PIP) in the CO.

The network layer competition model is always applicable, independent of technology and architecture choice, and entry level for competitors is easy. Customers can easily choose their SP, and
cost efficiently switch service provider. A lock-in situation might happen in case packages (e.g. triple play services) are offered by the PIP/NIP/SP as he can push down prices and compete in this way with CLECs making use of his network.

The highest competition model at application layer represents a new monopolistic situation where passive and active (network) infrastructure, as well as service provisioning is owned and operated by one actor (or consortium of actors). No competition is possible at this level, only a choice can made between application providers e.g. different VoIP provider, TV or HD providers, etc. by the customers. This model is in fact a degraded version of the physical infrastructure based competition model at trench level, as there is only one PIP instead of (possibly) multiple PIPs.

5.2. Introduction of real options analysis

A real option is the right but not the obligation to undertake some business decision, typically the option to make, or abandon a capital investment (Copeland and Antikarov, 2003). This type of analysis could of much interest when business cases for fiber access network rollouts are considered. Different actors in the value network could create real options on future value-generating actions during the course of the network deployment. This means that, based on the actual outcome of some uncertain evolutions, they will have the flexibility to choose the most value-generating action. A few examples for different actors are given below.

- ILECs could install in the current network rollout of xDSL extra infrastructure (ducts, fibers, flexibility points) that will facilitate the rollout of fiber in a latter stadium. In this case, extra investments made today, will give them the option to cost efficiently rollout fiber at a future stage. In case they are not (fully) migrating towards fiber, the cost for the option is not lost as this infrastructure could be sold to competitors.

- Local governments could change regulation procedures regarding physical telecom infrastructure e.g. requiring the installation of duct infrastructure to each premise in new housing areas. This can at a later stage be used for connecting the customers at a low cost to one or more fiber networks. This type of pre-installation could also be aligned with other 'utility' investments such as road, sewage, gas and/or water networks.

- Utility companies acting as PIP (past or current network investments) have the option to lease or sell their telecom infrastructure, depending on the current market situation.
• CLEC’s have the option to be less dependent of the ILEC by switching from LLU or bitstream access (via the ILEC network) to own network investments.

Further study and quantification of these real options in fiber network rollout form an issue for future research.

6. Conclusions

In this paper we have presented different strategies for future proof fiber to the home rollouts, based on four levels of competition: physical infrastructure, data link layer, network layer and application layer based competition. The different business roles, and their internal relations are presented. Many actors are involved in the whole process, such as governmental institutions, telecom operators, service and content providers and customers. The value networks, where actors are mapped onto the different roles, were presented for the different competition models.

Each actor could influence, and facilitate, the rollout decision for fiber to the home. Governmental instances should focus on making rules and regulation policies to facilitate the rollout of fiber access networks, this by communicating transparently about future policies so that the framework in which infrastructure developers act or will act, is clear and decisions can be taken. Current physical infrastructure owners (mostly ILEC and cable operators, but also new actors such as utility companies) can built out their network towards future proof fiber access networks. CLEC operators will have more options (LLU, bitstream access, rollout of own network) depending on the competition model. A separation of physical (and network) infrastructure and service provisioning will attract competition. A real options analysis for the different actors could furthermore shine a light on the value of different potential strategies considering uncertain market parameters (e.g. regulation, financing, market adoption, etc).

Acknowledgements

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References


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- Fournier P.-F., "From FttH pilot to pre-rollout in France", CAI Cheuvreux conference, June 26th 2007


FINAL PROGRAMME

Wednesday, 10 December 2008
9:00–9:30    Welcome and introduction
9:30–10:10   Introductory remarks
10:10–11:10  Session 1
11:10–11:30  Coffee break
11:30–12:30  Session 2
12:30–13:30  Session 3
13:30–15:20  Lunch
15:20–16:20  Session 4
16:20–16:40  Coffee break
16:40–18:40  Roundtable on Universal service
From 20:30   Tapas evening

Thursday, 11 December 2008
9:00–10:40   Session 5 (COST 605)
10:40–11:00  Coffee break
11:00–12:20  Session 6
12:20–14:00  Roundtable on The new role of regulation
14:00–15:30  Lunch
From 15:30   Enjoy winter in Seville
From 20:00   Flamenco Museum and Gala dinner

Friday, 12 December 2008
9:00–10:00   Session 7
10:00–10:50  CITI keynote presentation
10:50–11:10  Coffee break
11:10–12:10  Session 8
12:10–13:50  Roundtable on Infrastructures deployment
13:50–14:00  Closing address
INTRODUCTORY REMARKS

José Luis GÓMEZ BARROSO – UNED – Spain
Claudio FEIJÓO – IPTS-JRC-EC

Public private interplay in perspective

CITI KEYNOTE PRESENTATION

Raúl L. KATZ – CITI – Columbia University – United States

The economic crisis and the return of keystenism in next generation networks

ROUNDTABLE ON “UNIVERSAL SERVICE”

Chair: Claire MILNE – Antelope Consulting – United Kingdom

Colin BLACKMAN – SCF Associates / Info – United Kingdom
Jock GIVEN – Swinburne University of Technology – Australia
Edvins KARNITIS – Public Utilities Commission – Latvia
Armo WIRZENIUS – Teleplanning - Finland

ROUNDTABLE ON “THE NEW ROLE OF REGULATION IN PUBLIC-PRIVATE RELATIONSHIPS”

Chair: Brigitte PRESSL – Intereconomía Editor – Germany

Íñigo HERGUERA – Comisión del Mercado de las Telecomunicaciones – Spain
Gustavo PEÑA – Regulatel
Jean Paul SIMON – JPS Public Policy Consulting – France

ROUNDTABLE ON “INFRASTRUCTURE DEPLOYMENT – DESPLIEGUE DE INFRAESTRUCTURAS”

Chair: Ricardo ALVARIÑO – Subdirectora General de Infraestructuras – DG Telecomunicaciones, Ministerio de Industria Turismo y Comercio – Spain

Tomas RÍOS RULL – Director General Telecomunicaciones y Nuevas Tecnologías – Gobierno de Canarias – Spain
Manuel ORTIGOSA – Jefe de Servicio Planificación Tecnológica – Consejería de Innovación, Ciencia y Empresa, Junta de Andalucía – Spain
Joanna ARRANZ PEDRAZA – Coordinadora SATI - FEMP – Spain
Maite ARCOS – Directora General - Redtel - Spain
Pedro NAVARRO OROZCO – COIT Andalucía Occidental y Ceuta - Spain
SESSION 1.  PPI in a general perspective

Chair: Colin BLACKMAN – SCF Associates / Info – United Kingdom
Matthias EHRLER – SBR Juconomy Consulting – Germany
Igor BRUSIC – ÖFEG Ges.m.b.H – Austria
Wolfgang REICHL – ÖFEG Ges.m.b.H – Austria
Ernst-Olav RUHLE – SBR Juconomy Consulting – Germany

*Deployment of fiber optic networks within the framework of PPP projects*

Youngsun KWON – Information and Communications University – South Korea
Seungmi Yang – Daejeon University – South Korea

*Government involvement versus free market in boosting free Wi-Fi access: A more cautious approach is needed*

Carol C McDONOUGH – University of Massachusetts Lowell – USA

*Strategies for evaluating the appropriate public/private interplay in the telecommunications industry*

SESSION 2.  PPI in specific markets

Chair: Jock GIVEN – Swinburne University of Technology – Australia
Mirja PULKKINEN – University of Jyväskylä – Finland
Pasi TYRVÄINEN – University of Jyväskylä – Finland

*The e-society carriers: developments with communication services providers (CSP’s)*

Gary MADDEN – Curtin University – Australia
Randy BEARD – Auburn University – Australia

*Competition between blended traditional and virtual sellers*

José A. VALVERDE – IPTS-JRC-EC

*Potential and current impact of Web 2.0 applications on health policy and management processes*

SESSION 3.  Public vs. private action

Chair: Sergio RAMOS – Redtel – Spain
Gokce KURUCU – Çankaya University – Turkey
Ismail SAGLAM – TOBB University of Economics and Technology – Turkey

*Access regulation, regional competition and investment in network industries*

José Luis GÓMEZ BARROSO – UNED – Spain
Claudio FEIJÓO – IPTS-JRC-EC

*An overview of public/private policy tools for next generation infrastructures*
Public/private interplay in next generation communications. Programme

Gary MADDEN – Curtin University – Australia
Aaron MOREY – Curtin University – Australia

*The impact of privatisation and competition on telecommunications network growth and productivity*

SESSION 4. Universal service / Inclusion

Chair: Jean Paul SIMON – JPS Public Policy Consulting – France
Fernando HERRERA – Telefónica – Spain
Luis CASTEJÓN – Universidad Politécnica de Madrid – Spain

*An assessment of universal service obligation effectiveness to increase deployment of telecommunications network access*

Orada TEPPAYAYON – Chalmers University – Sweden
Erik BOHLIN – Chalmers University – Sweden

*Universal service: Some considerations for broadband access*

Geomina TURLEA – IPTS-JRC-EC
Constantin CIUPAGEA – Romanian Center for Economic Modelling – Romania

*Happy eInclusion?*

SESSION 5. Special COST 605 Session

Chair: Jose-Luis GÓMEZ-BARROSO – UNED – Spain
Oleksiy MAZHELIS – University of Jyväskylä – Finland
Pasi TYRVÄINEN – University of Jyväskylä – Finland
Lauri FRANK – University of Jyväskylä – Finland
Kimmo SUOJAPELTO – University of Jyväskylä – Finland

*Analyzing vertical software market evolution: the case of telecom OSS/BSS software*

Morten FALCH – Aalborg University – Denmark
Anders HENTEN – Aalborg University – Denmark

*Investment dimensions in a universal service perspective – Next generation networks, alternative funding mechanisms, and public-private partnerships*

Jan VAN OOTEGHEM – Ghent University – IBBT – Belgium
Sofie VERBRUGGE – Ghent University – IBBT – Belgium
Mario PICKAVET – Ghent University – IBBT – Belgium
Piet DEMEESTER – Ghent University – IBBT – Belgium

*Enter proof strategies towards fibre to the home*
Public / private interplay in next generation communications. Programme

Pedro PUGA – Obercom (Observatory for the media) – Portugal
Sandro MENDONÇA – Obercom (Observatory for the media) – Portugal
Gustavo CARDOSO – Obercom (Observatory for the media) – Portugal
Rita ESPANHA – Obercom (Observatory for the media) – Portugal

*Telecommunications for the needy: an exploratory approach from Portugal*

Sergio RAMOS – Redtel – Spain
Maite ARCOS – Redtel – Spain

*The role of Public Administration in developing the electronic communications sector: the operators’ perspective*

SESSION 6. New approaches

**Chair:** Raúl L. KATZ – CITI – Columbia University – United States

Marijn POEL – TNO and Delft University of Technology – The Netherlands
Linda KOOL – TNO – The Netherlands

*The policy mix for ICT innovation in The Netherlands: in search of new instruments, policy coherence and impact*

T.M. EGYEDI – Delft University of Technology – The Netherlands
J.L.M. VRANCKEN – Delft University of Technology – The Netherlands
J. UBACHT – Delft University of Technology – The Netherlands

*Inverse infrastructures: The policy gap regarding self-organizing systems*

Corina PASCU – IPTS-JRC-EC
Marc VAN LIESHOUT – IPTS-JRC-EC

*User-led citizen innovation at the interface of services*

Igor BRUSIC – ÖFEG Ges.m.b.H – Austria
Ernst-Olaf RUHLE – SBR Juconomy Consulting – Germany
Matthias EHRLER – SBR Juconomy Consulting – Germany
Wolfgang REICHL – ÖFEG Ges.m.b.H – Austria

*Emerging market models in telecommunications*

SESSION 7. Policy cases

**Chair:** Gustavo PEÑA – Regulatel

Adeyinka IYANDA – PHASE7 Public Sector Consulting Limited – Nigeria
Gbadebo Olusegun ODULARU – FARA – Ghana

*Reforms, private investment and efficient service delivery: case studies of selected sub-Saharan African telecommunications sectors*
Chinyelu ONWURAH – Ofcom – United Kingdom

Facilitation as light touch regulation: public-private interplay in standardisation

Nicola MATTEUCCI – Marche Politechnic University – Italy

Interoperability Provision in Next Generation Communications: the case of Italian DTV

SESSION 8. PPI case studies

Chair: Ramón COMPAÑÓ – IPTS-JRC-EC

Fabian SCHUSTER – SBR Juconomy Consulting – Germany
Ernst-Olav RUHLE – SBR Juconomy Consulting – Germany
Wolfgang REICHL – ÖFEG Ges.m.b.H – Austria

The interplay of stakeholders from different sectors for the deployment of communications infrastructure – a case study from Bahrain

A. NUCCIARELLI – Technische Universiteit Eindhoven – The Netherlands
B.M. SADOWSKI – Technische Universiteit Eindhoven – The Netherlands
P. ACHARD – Universita’ degli Studi dell’Aquila – Italy

Public-private partnerships for broadband access: Case study evidence from Italy and the Netherlands

Jorge INFANTE – Universitat Pompeu Fabra – Spain
Ramón SAGARRA – Barcelona Council – Spain
Carlos MACIÁN – Universitat Pompeu Fabra – Spain

Ducts, fibres, municipalities, barriers to entry and effective competition: A case study of successful public-private partnership in the provision of neutral FTTX infrastructure in Barcelona
UNED - Universidad Nacional de Educación a Distancia (National University of Distance Education), with the support of the Junta de Andalucía (Regional Government of Andalusia) and in collaboration with CITI (Columbia Institute for Tele-Information; Columbia University), is going to organise the conference "Public/Private Interplay in Next generation communications", which will be held in Seville (Spain) from 10 to 12 December 2008.
## PROGRAMME

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<td>9:30-10:10</td>
<td>Introductory remarks</td>
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<tr>
<td>10:10-11:10</td>
<td>Session 1. PPI in a General Perspective</td>
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<td>Roundtable on &quot;Universal service&quot;</td>
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<td>Tapas evening</td>
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<td>Session 6. New Approaches</td>
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<tr>
<td>From 20:00</td>
<td>Flamenco Dance Museum</td>
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