Techno-economic evaluations of FTTH roll-out scenarios
(Invited)

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With the continuous increase in bandwidth required per customer, access networks more and more become a bottleneck. The network operator will thus probably upgrade the access network and eventually deploy a full fibre to the home access infrastructure. Currently though, most telecom operators are reluctant to deploy FTTH in the access networks as this is a very cost intensive operation. Still fibre to the home might reduce operational expenditures (less failure sensitive), and a competitive advantage. In this view, a network operator wants to get (and keep) a clear and balanced view on the deployment costs of FTTH and the different trade-offs.

In this paper we present an approach for getting a clear view on the expenses for deploying FTTH. This approach starts with a detailed decomposition of all expenses (capital and operational) according to the different lifecycle steps: "planning", "deployment", "service migration" and "up and running operations". We add to each of the decomposed parts of the cost a high level view on the size, methods and tools for calculation and the most important parameters or risks. We further increase the level of detail by gradually zooming into those parts which are either most important (highest in size) or most unknown (highest risk).

Finally in the paper we use the suggested approach on a realistic case study in which we focus on a full, initially GPON based, FTTH deployment in one smaller city (of about 10000 residents) of Belgium. We follow the approach mentioned above and describe in each zooming step how more detailed calculations are made. The final outcome is a gradually more detailed view on the most important costs, insight in the trade-offs in each step and an integrated calculation model containing both CapEx and OpEx. We conclude with deducing general rules of thumb from the case study.

1. Introduction

Some FTTH deployment projects attracted a lot of attention recently. FTTH networks were successfully deployed in different cities such as Amsterdam [1], Vienna [2], Paris [3], Vasteras [4] and other. However, the overall number of FTTH customers throughout Europe is still very limited and most of the deployments fit within community initiatives. Traditional network operators are reluctant to any FTTH deployments. Both the unclear legal situation [5] and the expected high costs are cause to this. To make any profound decisions on FTTH deployment, an accurate cost model is to be used, given enough detail on differences between deployments in different regions.

There is already a lot of information on the typical infrastructure costs and fibre deployment costs. Several references describe typical values for both [6]. Still, as the investments for deploying a FTTH network are huge, it is important to model the costs in more detail. Most current approaches focus on the CapEx and look in much less detail to the OpEx of such network. As FTTH is expected to be the last step in the bandwidth evolution for the access and is also expected to last a long time (up to 50 years) it might make sense also to take these types of costs into account during installation. More in general, it is advisable to model first the largest parts of the overall expenses in more detail, regardless of whether they are CapEx or OpEx.

We start with proposing a typical breakdown of the overall expenses and their initially expected impact in section 2. From this breakdown we indicate which parts should be modelled in more detail.

This zooming approach and the detailed models for the different breakdown costs are described in the third section.

In the fourth section we apply this approach and the models found to estimate the expenses of a realistic deployment in which we focus on a full, initially GPON based, FTTH deployment in one smaller city (of about 10000 residents) of Belgium.

Finally we conclude with summary of the approach and the most important models and results obtained from the case study.

2. FTTH Deployment Cost Breakdown

The costs of a FTTH deployment will be depending on a lot of parameters. First of all geographical and demographical parameters will have a very large impact on the costs. It is for instance very clear that a FTTH network rollout will be more viable for a dense residential region. Also the different technological options can account for huge differences in cost now and in future scenarios. The most obvious parameter is here the choice between a passive optical network architecture (PON) where the customers are connected to the central office (CO) in a point to multipoint fashion, versus an active ethernet or home run fibre network architecture (HRF) in which the customer has a dedicated connection to the CO (in the case of HRF there is even a dedicated fibre up to the CO). In the first phase of constructing a business model it is thus very important to gather all input data and information. This information is then used as input and for building a cost model for the FTTH deployment project (or other project at hand). Finally, when combining the costs with revenues, an economic evaluation of the FTTH deployment is made.

In this paper we focus on the costs and more in particular how to model all costs with the right level of detail. For doing this we start from a life-cycle analysis. When looking at the life-cycle of an FTTH network, we can distinguish the following different stages:

1. planning
2. deployment
3. customer migration and service provisioning
4. up and running
5. teardown

As FTTH is a large project involving a lot of trenching work to be done it needs a large amount of upfront planning. Once the deployment plan is final, the actual deployment can be started. This part of the life-cycle is typically indicated as the largest cost consuming 60%-70% [7] of the total expenditures for the project. It is clear that this part should be modelled in more detail. Once the network is in place, the customers are to be connected to the network. We call this part the customer migration and service provisioning. Especially making the physical connection from the network to the customer is expensive. Once the network is up and running it should be maintained in this state which comes down to monitoring, maintenance and repair actions. The cost for repair is unknown and could pose an important maintainability risk in the long run. Additionally there are the fixed costs of infrastructure containing the power consumption, housing, right of ways, etc. Finally, as the fibre network is expected to have a very long life time, there is no intention to teardown the fibre network or take this action into account in the cost model.

3. Zooming in on the costs

Considering the life-cycle proposed in the previous section, we zoom in on the expectedly largest costs. It is clear that the deployment cost will be the highest and should be modeled in much more detail. We will start with this cost and indicate how to model it in more detail and how to proceed with the zooming until we get a fairly detailed and integrated cost model. Figure 1 contains a detailed overall view on the calculation model.

Figure 1. overview of the calculation and zooming model

3.1 Deployment costs

In this part we focus on the costs involved in the physical deployment of an FTTH network. The cost of equipment is much smaller than the manpower costs for creating the trenches where the FTTH is buried in.

We zoom further in on the trenching costs and considering the huge impact on the total cost, we modeled this in detail. The optimal trenching topology can be calculated by constructing a Steiner-tree over the full road-topology and connecting all customers. The Steiner tree problem tries to solve the problem of connecting N points to each other with a minimal cost tree structure. More in detail here we consider the Steiner tree problem in graphs. The formal definition of this problem is Given a weighted graph $G(V,E,w)$ and a vertices subset $S \subseteq V$, find a tree of minimal weight which includes all vertices in S. This problem is NP complete and we thus relied on existing heuristic methods [8] for calculating a near optimal tree structure. It is clear that large savings are possible if (part of) the network can be installed without trenching, for instance by means of aerial deployment. Other possible solutions exist, such as reusing existing ducts (even after extracting the existing copper cables [9]), reusing the sewage system, attaching the cables to the facades, etc. Also different technologies are developed for minimizing this part of the costs by means of for instance hollow sidewalk boundaries or micro-trenches, etc. Several options are not allowed by legislation or require additional infrastructure to be available or installed. In a full cost model the different installation allowed alternatives should be taken into account in constructing the cost model.

The inside and outside plant equipment is expected to be much smaller. We can model these by attaching a representative cost to each customer. A little bit more detail is required by estimating the amount of flexibility points and splitters required in the network according to the number of customers and possibly some correction factor as not all equipment will be 100% used (e.g. the 1:32 splitters might connect less than 32 customers on average). The central office can be dimensioned much in the same manner. However the dimensioning of some parts of the equipment will not be directly dependent on the number of customers, but rather on the number of incoming fibres. For example the optical distribution frame which will physically couple the incoming fibres to the cables attached to the OLT and provide flexibility here. It should be noted that in case of HRF this number of incoming fibres is the same as the number of customers, in case of a PON this is smaller. Other parts, such as climate or powering control will be depending on the number rooms in use. The coating of the different fibres in one cable is typically the largest cost of the cable more or less regardless of the number of fibres in the cable. We thus model the fibre and cable cost by selecting different cables (with a fixed number of fibres) for the feeder and distribution part of the network. In more detail, a calculation of the actual number of fibres could be made in which also the granularity of cables sold should be considered.

3.2 Customer migration and service provisioning

The second largest group in the cost breakdown is formed by the costs for connecting the customers to the network and subscribing them to a specific service. As was already clear the physical installation will take by far the longest and will most probably also cost most. The cost of the CPE should also not be discarded. The costs for the CPE are very straightforward as they are directly linked to the number of customers. The other costs are minor and have been modeled in much less detail.

Considering the important cost for making the physical connection to the customer we modeled this in detail using an activity based costing approach (ABC) in which we

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model the process of installation by means of a flowchart and attached expected timings to each of the rectangles and probabilities to each of the outcomes of a diamond. These have been indicated in [10]. As mentioned before there are a lot of different approaches towards installing the fibre in the streets and they might all have an impact on the cost of installation. Additionally it might prove beneficial to connect customers at the same time as the installation of fibre in the street. This way all equipment is already available and, in case of buried, the ground is already opened up. It will thus cost less to make the connection at this point. On the other hand it might prove a very challenging task from an administrative point of view.

3.3 Costs for keeping the network up and running

Finally we look into the costs for keeping the network and the services over the network up and running. We focus here on cable cut repair and energy costs.

The rationale for the focus on cable cut repair lies in the fact that these costs are less known for a nationwide rollout and contain a large cost for going to the location, where failure statistics of customer premises equipment (CPE) and other equipment is better known and replacement is most possibly incorporated in a maintenance contract with the vendor and could thus also be represented there. As this is part of a contract it is not necessary to develop a model for this cost, but incorporate the vendors offer in the full cost model. For modeling the repair cost, we started from the operational process model and used ABC for estimating the cost. Therefore we also attached expected timings to each of the rectangles and probabilities to each of the outcomes of a diamond. These have been indicated in [10].

In the continuous cost of the infrastructure, we neglected the housing cost as we expected for the CO to make reuse of existing housing and thus not representing a cost. When this number could be reduced or extra housing should be found, a dedicated model could be made for this cost, and will be depending on the amount of equipment and the amount of floor space this requires. Calculating the power consumption is reasonably easy given the equipment in the central office and the equipment in the field (in case of an active network). Finally the power consumption for cooling the equipment can be modeled in less detail by estimating it at half the working power consumption.

As mentioned, currently the other operational costs for keeping the network up and running have not been modeled. As we do not expect that these expenses have a great impact or great risk, they could easily be modeled using a straightforward model. This could for instance be a fixed cost or a cost proportional to the number of customers (e.g. marketing or pricing and billing), or equipment count (e.g. maintenance). Finally as for instance the marketing and pricing and billing will probably not be influenced a lot by the type of technology, they could also be expected to stay the same company-wide and thus be neglected in the business case.

4. Case study

As an exemplary case we calculated the FTTH deployment costs for a greenfield scenario for Zele (Figure 2). Zele is a Belgian town of about (potential) 10000 customers, meaning 10000 homes, including currently empty parcels. In this calculation we envisaged a PON architecture with a centralised 1:32 split, meaning that we have per group of 256 customers a flexibility point in which we connect the 256 distribution fibres to 8 feeder fibres coming from the CO by means of 1:32 splitters. Four main cost categories have been considered for an expected lifetime of 10 years:

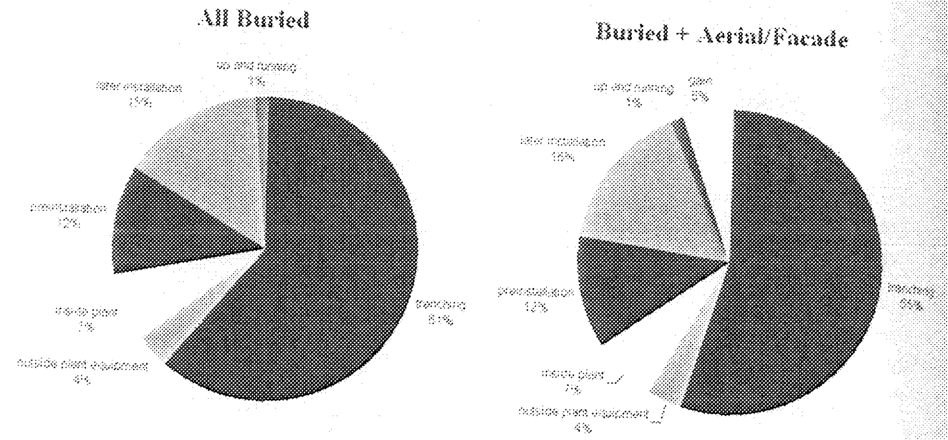

Figure 2: FTTH cost breakdown for Zele in case of (left) all buried, (right) using aerial and façade

- Outside plant includes both trenching and equipment cost (splitters and flexibility points) and adds up to 65% respectively 62% (when the costs are scaled back to 100%) of all costs.
- Inside plant is basically the cost of one central office (for the 10000 customers under consideration) and represents 7% of the costs.
- Service migration for connecting the customers to the new FTTH network means 27% of the costs (assuming a take rate of 100% and all customers connected up front).
- Up and running costs represent around 1% of the cost. This is the expected costs for cable cut repair and energy consumption over 10 years.

Overall, this leads to a cost per home passed of about 1050 Euro and a cost per home connected of about 1450 Euro for a 100% take rate in an all buried case. In case of an optimal usage of aerial deployment this can be reduced to about 950 euro per home passed or 1375 Euro per home connected. Drastically lower take rates can have a major impact on the expected cost per home connected (as volume independent costs like outside plant deployment costs contribute to the majority of the overall cost). In the considered case the cost per home connected grows to 2900 euro in case of only a 50% take rate.

4.1 Deployment costs

The total outside plant contributes up to 65% of the total costs in case of all buried and 62% when using aerial and façade installation for reducing the trenching costs. It is clear from the calculations that this option really lowers the costs as there is a 5% overall gain over the all buried case. It should be noted that although in this second case only 9% of the cables is installed aerial this still connects almost 40% of the homes. The inside plant contributes significantly less to the overall costs than the outside plant (65% or 62% vs. 7%).

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Considering outside plant, the main cost contributor in the considered case for Zele is clearly trenching with 94% of outside plant cost, splitters account for nearly 1.5% and flexibility points (both the physical equipment and installation) for the remaining 4.5%.

The inside plant costs can be split in a part proportional to the number of fibres, a part proportional to the number of customers and a part proportional to the number of central offices. For the considered case in Zele, we neglected the CO-driven costs for airco and backup generator. 54% of the inside plant cost is fibre-driven (optical MDF, OLT cards, optical jumpering, internal cabling), 46% is customer-driven (chassis, rack, shelf, control)

4.2 <u>Service migration costs</u>

The service migration accounts for 27%-28% of the overall cost. Within this category we can again distinguish three parts. The physical installation (cable) accounts for 15% of the service migration cost, the technical installation for 74% and the administrative work for 11%. The calculations in both cases started from 50% pre-installed customers and 50% later installations. Connecting a customer at a later point in time will clearly cost more than installing him right away. Still these results did not take the administrative overhead into account which comes with a massive pre-installation of customers.

4.3 <u>Costs for keeping the network up and running</u>

The repair process cost is taken together with the energy cost in Figure 2 and account in the exemplary case for 1% of the total cost. In the first place this means that operating a fibre network could be less costly than operating a copper network. However, it should be noted that the exemplary case uses a PON architecture with a split factor of 1:32, where an active architecture would thus contain up to 32 times more fibres in the feeder cables. Also the distance from the client to the CO and to the first splitter could have an important impact on the costs. Finally, as also discussed in detail in [11], the operator could make use of different approaches towards resilience in the FTTH network for reducing the repair costs.

5. Conclusion

Deploying a new FTTH network in a region involves a tremendous work and costs. Literature mentions a typical 1500 Euro per home connected in highly residential regions and much more in lower residential regions. It is clear that large savings are possible on such a huge cost and thus a detailed modelling is required to make the best upfront decisions.

In order to construct such model, it is impossible to simply rely on a detailed CapEx model alone, but rather an integrated model including all facets of the costs is required. In this paper we proposed an approach which starts from the life-cycle of a FTTH network and zooms in on the largest or most unknown costs first. We complemented this life-cycle with a more detailed cost-cause analysis in which we indicated which parts should be focussed on and why. Finally we investigated which models are best suited to estimate the costs for these parts.

Finally we used this approach on a realistic example in which the cost of a FTTH deployment is calculated for a smaller (not highly residential) Belgian city of 10000 inhabitants. The results are comparable to the typical breakdown as mentioned in literature with a 60-70% cost for the trenching. The results also show the high cost for the actual connection and subscription of the customer which consumes roughly 35% of the total cost. Finally the remaining costs for installation of the inside plant and for keeping the network up and running are less high.

The results also show the power of the zooming approach in which the focus of increasing the level of detail is placed on the part with the highest cost. It is for instance clear that a calculation of the (near) optimal tree structure, taking different alternatives into account is justified and even mandatory given its very high cost. The results for instance showed that a gain of 5% is possible using alternative solutions. The results also showed that pre-installing customers can be used to get additional gains.

Acknowledgements

The work described in this paper was carried out with the support of the BONE-project ("Building the Future Optical Network in Europe"), a Network of Excellence funded by the European Commission through the 7th ICT-Framework Programme, and of IWT-Flanders through the IWT-project "Cost modeling in a converged communications environment". Finally the authors would also like to thank Erna Del Turco, Paulo Crivellari, Wim Bouckenooghe and Marc Van Quekelberghe at Belgacom for their valuable input for evaluating this case.

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