Optimisation of Heterogeneous Migration Paths to High Bandwidth Home Connections

Frank Phillipson

The Netherlands Organisation for Applied Scientific Research (TNO),
P.O.Box 96800, 2509 JE The Hague, The Netherlands
Email: {frank.phillipson}@tno.nl

***Abstract*—Operators are building architectures and systems for delivering voice, audio, and data services at the required speed for now and in the future. For fixed access networks, this means in many countries a shift from copper based to fibre based access networks. This paper proposes a method to optimise the migration path, heterogeneously per central office area, using geometric models as input. The method results in a detailed migration path that meets a required bandwidth coverage. For this, two models are presented. The first minimises the total costs meeting a bandwidth requirement per period, the second minimises the deviation from this bandwidth requirement meeting a budget constraint per period. While the data used for the migration path optimisation is in practice hard to gather, the use of geometric modelling is proposed. This modelling approach can estimate the total CapEx of a migration step using only two simple parameters per Central Office area.**

***Index Terms*—Access networks; Migration Optimisation; Geometric Models**

I. Introduction

Broadband internet is becoming a common utility service. Using connected electronic devices in and outside our homes, we use more and more data and demand connectivity 24/7. The used services are asking more bandwidth due to the integration of video into numerous services. Most of the home connections, access networks and systems, of telecom operators are not prepared to offer this, where incumbent operators mostly use copper telecommunication networks offering ADSL (Asymmetric Digital Subscriber Line) or VDSL (Very High Bitrate Digital Subscriber Line) techniques as service. Digital subscriber line (DSL) is a family of technologies, used to transmit digital data over copper lines. The operators have to make the costly step to Fibre to the Cabinet (FttCab), Fibre to the Curb (FttCurb) or, even more costly, the full step to Fibre to the Home (FttH), Fibre near the home (FntH) or Fibre to the Air (FttA). An example of FntH and FttA is a wireless home connection or a Hybrid fibre-wireless (FiWi) access network, where fibre is brought to a location near the homes, e.g., street lights [1], and the remaining distance is covered by WiFi or WiMax [2] [3]. However, the roll out of all these fibre connections will be taking in many countries too long to compete with the cable TV operators, active in those countries, who can offer the required bandwidth using DOCSIS, Data Over Cable Service Interface Specification. on their Hybrid Fibre Coaxial (HFC) networks at this moment. This urges the operators to take intermediate steps, such as FttCurb, and to think about the optimal migration strategy.

The incumbent telecom operators can choose between various topology types to offer. In this paper, the term 'topology' is used for the way the physical fibres and equipment are designed. It comprises the question where to deploy fibres, where to deploy copper, where is the active or passive equipment placed. Each topology can run multiple technologies. For example, in the 'Full Copper' topology the operator offers the services from the Central Office. The operator still can choose to offer ADSL or VDSL (containing here all VDSL based technologies such as VDSL, VDSL2, Vectored VDSL2, Vplus etcetera) technology for this service. In this paper, four topology types are distinguished (see Fig. 1):

1) Full Copper: services are offered from the Central Office (CO) over a copper (twisted pair) cable, using DSL techniques.
2) Fibre to the Cabinet (FttCab): the fibre connection is extended to the cabinet. From the cabinet the services are offered over the copper cable, using DSL or G.Fast techniques.
3) Hybrid Fibre to the Home (Hybrid FttH): services are offered from a Hybrid FttH Node, which is connected by fibre, close to the customer premises, in the street or in the building. Here again VDSL and G.Fast techniques can be offered.
4) Full Fibre to the Home (Full FttH): the fibre connection is brought up to the customer premises.

If the operator starts with a Full Copper topology in a certain area, he has to decide on the next step: bringing the fibre connection all the way to the customers or use an intermediate step, where he brings the fibre closer to the customer, e.g., FttCab. Note that the operator can have a heterogeneous network, where in different areas a different topology is deployed and a different starting position for migration is found. To make in a certain area the decision mentioned before, the operator has to look at the pros and cons of all the options. For example, the deployment of FttCab can be much faster than Full FttH, as it requires less digging, the last part of the connection from the street to the access

 ISBN: 978-1-61208-544-9

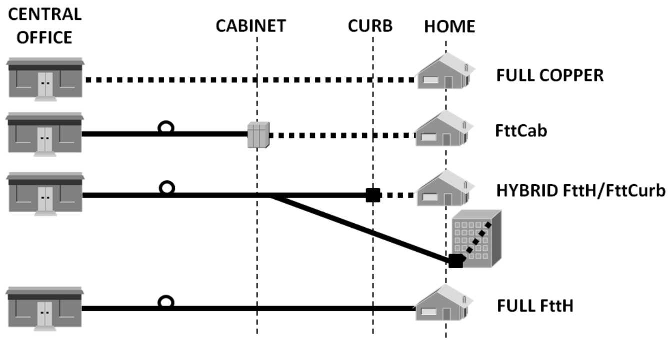

Figure 1. Four topologies.

node in the house does not have to be installed, and it meets the growing bandwidth demand for now and the near future. If, in future, this demand exceeds the supplied bandwidth, the remaining part to the residence can be connected with Full Fibre or using Hybrid Fibre as extra intermediate step. If the demand does not exceed the supplied bandwidth, for example it reaches some level of saturation, no further migration is needed, saving a lot of investments. However, when Full FttH is the expected final solution, using intermediate steps would incur investment and installation costs that might be lost and not reused.

This decision can be made on strategic level, for a bigger region or a whole country, or more tactical/operational within a region. In this paper, the option that the operator can decide per Central Office area which topology or technology to offer is regarded. This means that the operator is offering broadband as a service, instead of offering for example FttH as a service. If an operator decides on the topology or technique per Central Office area and per period (e.g., year), he can develop a detailed migration path that meets, for example, a bandwidth coverage in a larger area. This option is called a heterogeneous optimal migration path in contrast to a homogeneous optimal migration path, where one migration path is used for all Central Office areas within the bigger region. This is the first part where the novelty of this paper is in. Up to now, other papers only considered uniform migration paths or single migration paths.

The second part where this paper is novel, is the data used for the migration path optimisation. To estimate the costs of a topology and the migration from one topology to another topology, for each migration an optimal planning should be made. We propose to solve this by using the geometric modelling, as presented in [4] [5].

Concluding, in this paper, we present a methodology that can be used by operators to design their heterogeneous topology migration path from Full Copper to Full FttH, meeting their business requirements. First we start with a literature survey on related models. In Section III, a model is presented to optimise the heterogeneous migration paths. In Section IV, a method is presented to gather to input for the migration path optimisation using Geometric models. In Section V, the optimisation method is demonstrated by a case study. Finally, in Section VI, some conclusions are presented.

II. Literature

Migration within telecommunication network is a topic in many Techno-Economical studies. In these studies the economic sanity of some choices are investigated. The European projects IST-TONIC [6] and CELTIC-ECOSYS [7] resulted in various upgrade or deployment scenarios for both fixed and wireless telecommunication networks, published in [8] and [9]. A major question in these studies is when to make the decision to roll out a FttC/VDSL network or a Full FttH network. Based on demand forecasts, it was shown that it is profitable to start in dense urban areas, wait for five years and then decide to expand it to the urban areas. With the use of real option valuation the effect of waiting is rewarded to identify the optimal decision over time. In [10] [11] the OASE approaches are presented for more in depth analysis of the FttH total cost of ownership (TCO) and for comparing different possible business models both qualitatively and quantitatively. The work of Casier [12] presents the techno-economic aspects of a fibre to the home network deployment. First he looks at all aspects of a semi-urban roll-out in terms of dimensioning and cost estimation models. Next, the effects of competition are introduced into the analysis. The work in [13] presents a multi-criteria model aimed at studying the evolution scenarios to deploy new supporting technologies in the access network to deliver broadband services to individuals and small enterprises. This model is based on a state transition diagram, whose nodes characterise a subscriber line in terms of service offerings and supporting technologies. This model was extended for studying the evolution towards broadband services and create the optimal path for broadband network migration. A similar kind of model is presented in [14] [15], where also an optimal strategy is proposed using a dynamic migration model. They study the best migration path including CAPEX, OPEX and revenues. Several fixed access technologies are taken as multiple intermediate steps. A more recent study [16] proposes several migration strategies for active optical networking from the data plane, topology, and control plane perspectives, and investigates their impact on the total cost of ownership but does not optimise.

Finally, our own previous work was about the benefits of a migration path as alternative for the direct step from Full Copper to FttH [17] and a Techno-Economic model [18] that can calculate the effect of offering different topologies and technologies in access networks (in migration) on market share, revenues, costs and earnings.

As said earlier, all these approaches (if optimising) only consider uniform or single migration paths and do not include the possibility of using geometric models as input.

III. Migration model

A migration path is defined here as a path from one topology/technique combination to a destination topol-

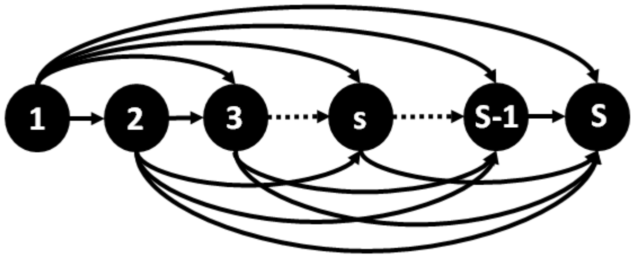

Figure 2. Migration paths.

ogy/technique, possibly using other topology/technique combination as intermediate steps. Analogue to [14] we use a figure to clarify the idea, see Fig. 2. Each node here is a topology/technique combination. One can choose a path from node 1, typically Full Copper/ADSL, to node S, typically FttH. So examples for the paths are: Full Copper/ADSL to FttH, Full Copper/ADSL to FttCab/VDSL to FttH, Full Copper/ADSL to FttCab/VDSL to FttCurb/G.Fast, etcetera. The focus in this paper is on an area that consists of multiple Central Offices, which is the location of the switching equipment, to which subscriber home and business lines are connected on a local loop, for example a city or a district. The goal of the operator is to offer in this district a certain bandwidth coverage (per year), given a budget (per year) and possibly other constraints. A bandwidth coverage can be a single value, e.g., 'I want to offer 100 Mb/s in 2017', or a distribution over various bandwidth values in a number of years. An example of this distribution over years is presented in Table I. In the table is stated that in 2018 (at least) 60% of the houses need to have (at least) 100 Mb/s, at least 40% of the houses need to have (at least) 200 Mb/s and (at least) 10% need (at least) 300Mb. The percentages do not add up to 100% while they are exceedance probabilities. If all houses have a connection that offers 500 Mb/s the bandwidth coverage demand is met, obviously.

TABLE I. COVERAGE GOAL.

Year	100 Mb/s	200 Mb/s	300 Mb/s
2018	60%	40%	10%
2021	80%	60%	20%
2024	90%	80%	40%

Now, the problem can be defined as a mathematical Mixed Integer Programming Problem. The notation that is used is presented in Table II. First the objective function is defined as:

$$\min \sum_i \sum_j \sum_l \sum_t c_{ijl} x_{ijlt}. \quad (1)$$

This objective minimises the total costs for the migration and

TABLE II. DEFINITIONS

Notation		Description
i and j	=	indices for topologies/technology;
l	=	index for location, here CO area;
t	=	index for time period;
d	=	index for distance, e.g., 200, 400, 600 m;
y_{ilt}	=	1 if technology i active on time t, location l
x_{ijlt}	=	1 if migration from i to j in year t for location l;
c_{ijl}	=	migration costs going from i to j location l
o_{ilt}	=	OpEx technology i active on time t, location l
R_{ild}	=	Number houses reached by i within d meter for location l;
RT_l	=	Total number premises for location l;
G_{td}	=	Requested percentage of houses in total area, reached within d meter on time t;
B_t	=	Maximum budget in time t;

needs to be met under the following constraints:

$$\sum_i \sum_j x_{ijlt} \leq 1, \quad \forall t, l \quad (2)$$

$$\sum_i y_{ilt} = 1, \quad \forall l, t \quad (3)$$

$$x_{ijlt} \geq \frac{1}{2}(y_{jlt} - y_{jlt-1}) - \frac{1}{2}(y_{ilt} - y_{ilt-1}) - \frac{1}{2} \forall i, j, l, t \quad (4)$$

$$\frac{\sum_i \sum_l R_{ild} \cdot y_{ilt}}{\sum_l RT_l} \geq G_{td}, \quad \forall t, d \quad (5)$$

This model will be called the base model. In (1) the total investment cost (CapEx) is minimised. In (2) it is made certain that there is not more than 1 migration step per year per location. Equation (3) makes sure that each location has each year exactly 1 topology. Equation (4) creates the migration steps. The right term can only be greater than zero if (and only if) $(y_{jlt} - y_{jlt-1}) = 1$ and $(y_{ilt} - y_{ilt-1}) = -1$, which indicates that there is a transition from technology i to technology j. In (5) the demanded bandwidth coverage is required.

An alternative objective function is realised when adding the operational cost, or OpEx. This alters the objective function in:

$$\min \sum_i \sum_j \sum_l \sum_t c_{ijl} x_{ijlt} + \sum_i \sum_l \sum_t o_{ilt} y_{ilt} \quad (6)$$

An alternative model is the model in which there exists a budget constraint per time period. In this formulation the budget constraints are hard, where the gap between the realised and demanded bandwidth per year is minimised:

$$\min \sum_t \sum_d \left(G_{td} - \frac{\sum_i \sum_l R_{ild} \cdot y_{ilt}}{\sum_l RT_l} \right), \quad (7)$$

under the following constraints:

$$\sum_i \sum_j x_{ijlt} \leq 1, \ \ \forall t, l \quad (8)$$

$$\sum_i y_{ilt} = 1, \ \ \forall l, t \quad (9)$$

$$x_{ijlt} \geq \frac{1}{2}(y_{jlt} - y_{jlt-1}) - \frac{1}{2}(y_{ilt} - y_{ilt-1}) - \frac{1}{2} \forall i, j, l, t \quad (10)$$

$$\sum_i \sum_j \sum_l c_{ijl} x_{ijlt} \leq B_t, \ \ \forall t \quad (11)$$

where (11) is added as budget constraint.

IV. Input from Geometric model

In the previous section two parameters are used, that are not that easy to get, namely c_{ijl}, the cost for migration from i to j on location l, and R_{ild}, the number of premises reached by i within d meter on location l. To get the value of these parameters, for each migration an optimal planning should be made. We introduce an alternative for this problem by using the outcomes of geometric modelling, as presented in [4] [5]. This means that we start by a simple set of parameters per (currently) active node: the total cable length (D) and the capacity of this node (n), which equals the number of premises connected. As is shown in [5] from these parameters the geometric density of the premises can be derived. With this geometric density we can estimate the number of new active locations that a next technology needs in this area to achieve a certain distance coverage and, consequently, the bandwidth coverage. From this number of active elements the costs of the migration can be estimated. Next, using the same density also the cable and digging distances to connect those new active elements can be estimated.

To illustrate this approach, think of an area, currently equipped with VDSL2, that contains $n_1 = 1,000$ houses. The given total cable length equals $D_1 = 875,000$ meter. Now, the parameter d, which indicates the house density of the area, expressed in the (average) width of the premises, can be derived by solving (using $s_1 = \sqrt{n_1}$):

$$d = \frac{D_1}{2 \cdot s_1 \cdot \lceil \frac{1}{2} s_1 \rceil \cdot \lfloor \frac{1}{2} s_1 \rfloor}. \quad (12)$$

Resulting in $d_D = 57,7$ for the given example. Let us assume that in the next topology, let us assume V-plus, we want to reach 85% within 400 meters. From [4] we know the probability distribution of the individual distances of the houses to the active node: it can be estimated by a Normal distribution $F_{\mu,\sigma}(x)$ with $\mu_2 = \frac{D_2}{n_2}$ and $\sigma_2 = \frac{M-\mu}{2}$ where M_2 represents the maximum cable distance in the second topology using [5]:

$$M = 2 \cdot \lceil \frac{1}{2} s_2 - 1 \rceil \cdot d + 0.5d, \quad (13)$$

$$s_2 = \sqrt{n_2}, \quad (14)$$

and the total cable length in the second topology

$$D_2 = 2 \cdot d \cdot s_2 \cdot \lceil \frac{1}{2} s_2 \rceil \cdot \lfloor \frac{1}{2} s_2 \rfloor. \quad (15)$$

Now, the question is to choose n_2 such that $F_{\mu(n_2),\sigma(n_2)}(300) = 0.90$. This can be solved numerically and leads to the following values $n_2 = 100$, $M_2 = 490$, $D_2 = 28800$, $\mu_2 = 290$ and $\sigma_2 = 100$. This means that to meet this requirement of 85% within 400 meter, 10 new nodes should be installed. It takes 28800 meter of digging and (fibre) cable to connect these nodes.

V. Case study

In this section a case study is presented introducing a small city with 40 cabinets and 18,500 houses. The current employment is ADSL. The operator has a bandwidth coverage goal, expressed in percentage of the houses that is within a certain distance from the active equipment. The coverage goal is shown in Table III. For example, the goal is to have 70% of the houses within 400 meter in 2021.

Table III. Coverage goal.

Year	600m	400m	200m
2018	70%	40%	20%
2021	85%	70%	30%
2024	85%	85%	40%

Table IV. Per period optimisation - base model.

Year	ADSL	VDSL	V-plus
2018	23	7	10
2021	17	7	16
2024	5	7	28

Table V. Overall optimisation - base model.

Year	ADSL	VDSL	V-plus
2018	25	0	15
2021	18	1	21
2024	8	6	26

Two cases are distinguished. In the first case the operator tries to meet the distance requirement for each year independently and optimally. This means that the operator optimises the design of each area without knowledge of future networks, topologies and technologies. In the second case the operator tries to meet the requirements for the total time horizon, using the methodology of Section III. For each cabinet, for each 3-year period, the operator can chose between doing nothing, implementing VDSL and implementing V-plus, each with its own costs and bandwidth consequences. Now, the operator tries to make the decisions such that the total migration costs are minimal, meeting the distance coverage requirements for each period as modelled in the base model of Section III. The used costs for digging and equipment are based on the (Sub-Urban) numbers of [19].

The result of the optimisation (only using Excel and OpenSolver [20]) of the two cases is depicted in Table IV for the per-period optimisation and Table V for the overall

 ISBN: 978-1-61208-544-9

optimisation. In the per-period optimisation in the first year (2018) more VDSL is chosen, as this is a cheaper solution to meet the 2018 requirements. In the overall optimisation the more expensive choice for V-plus is made, as this is more ready for the future. In the other two stages more or less the same choices are made. This leads to the total overview of costs as depicted in Fig. 3, where the total costs of the overall optimisation are lower, but the costs in the first year are higher. All costs are expressed in Net Present Value, with an average cost of capital of 6%, making the values in the various years comparable.

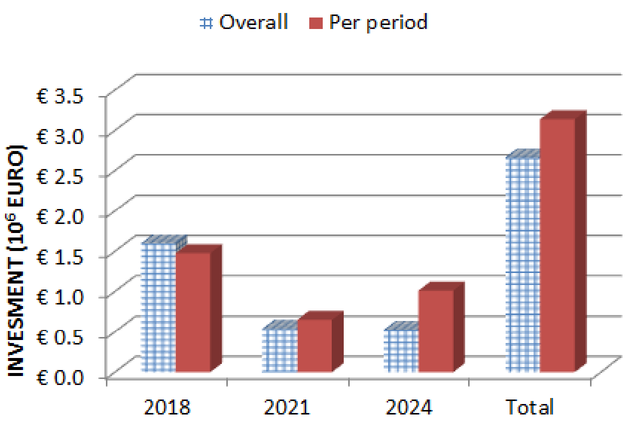

Figure 3. Investment costs.

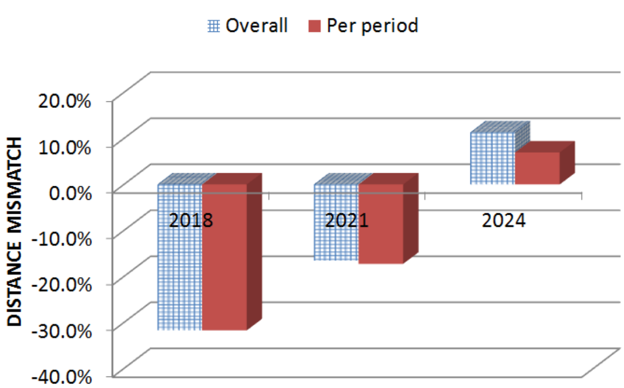

Figure 4. Meeting the bandwidth demand in the alternative model.

If the alternative model is used with a maximum budget of 750,000 euro per period, the results are as depicted in Fig. 4. In the first two year the bandwidth demand cannot be met, with a cumulative difference of 32% for the both approaches. This means that the sum of the differences between the number of houses reached within a certain distance and the requested percentage for all distances in a certain year equals 32%. In the second time period there also is almost no difference (0.7%), but in the third period, the small differences in the first two periods pay off, by a big difference in realisation (6.9% versus 11.3%). This means that the overall optimisation realised a plus on coverage of more than 4%.

TABLE VI. PER PERIOD OPTIMISATION - ALTERNATIVE MODEL.

Year	ADSL	VDSL	V-plus
2018	30	0	10
2021	13	2	15
2024	12	3	25

TABLE VII. OVERALL OPTIMISATION - ALTERNATIVE MODEL.

Year	ADSL	VDSL	V-plus
2018	31	0	9
2021	24	0	16
2024	10	4	26

The result of the optimisation of the two cases is depicted in Table VI for the per-period optimisation and Table VII for the overall optimisation. What can be seen in this example is that the alternative model over-compensates the under performance in the first two periods by over performance in the last period. This can be prevented by an other choice of objective in this model (Eq. 7), such as

$$\min \sum_t \sum_d \max\left(0, G_{td} - \frac{\sum_i \sum_l R_{ild} \cdot y_{ilt}}{\sum_l RT_l}\right) \tag{16}$$

or

$$\min \sum_t \sum_d \left(G_{td} - \frac{\sum_i \sum_l R_{ild} \cdot y_{ilt}}{\sum_l RT_l}\right)^2 . \tag{17}$$

Equation 16 is the best in preventing this phenomenon, while compensating is not possible: the negative terms are set to zero. Equation 17 tries to get results close to zero, preventing big deviations. Both alternatives will result in a model that is harder to solve than before by introducing a non-linear objective.

VI. CONCLUSION

In this paper, we presented a methodology that can be used by operators to design their heterogeneous topology migration path from Full Copper to (Full) FttH, meeting their business requirements. Heterogeneous means that the operator decides per Central Office area the topology or technique per period (e.g., year), resulting in a detailed migration path that meets a required bandwidth coverage in the larger area. For this, two models were presented. The first minimised the total investment (CapEx) and operational costs (OpEx), such that the bandwidth requirement per period was met. The second minimised the deviation from this bandwidth requirement meeting a budget constraint per period.

The data used for the migration path optimisation is in practice hard to gather. For this, the use of geometric modelling was proposed, with which the total CapEx of a migration step can be estimated using only two parameters per Central Office area, the total existing cable length and the capacity of this node.

Finally, the two models were demonstrated in two case studies that showed the gain that can be realised by the migration path optimisation.

 ISBN: 978-1-61208-544-9

REFERENCES

[1] T. Vos, *Using Lampposts to Provide Urban Areas with Multiple Services*. MSc Thesis, Erasmus University Rotterdam and TNO, 2016.

[2] N. Ghazisaidi, M. Maier, and C. M. Assi, “Fiber-wireless (fiwi) access networks: A survey,” *IEEE Communications Magazine*, vol. 47, no. 2, pp. 160–167, 2009.

[3] F. D’Andreagiovanni, F. Mett, and J. Pulaj, “Towards the integration of power-indexed formulations in multi-architecture connected facility location problems for the optimal design of hybrid fiber-wireless access networks,” in *OASIcs-OpenAccess Series in Informatics*, vol. 50. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2016, pp. 1–11.

[4] F. Phillipson, D. Worm, N. Neumann, A. Sangers, and S.-J. Wiarda, “Estimating bandwidth coverage using geometric models,” in *Networks and Optical Communications (NOC), 2016 21st European Conference on*. IEEE, 2016, pp. 152–156.

[5] F. Phillipson, “Estimating ftth and fttcurb deployment costs using geometric models with enhanced parameters,” in *Networks and Optical Communications-(NOC), 2015 20th European Conference on*. IEEE, 2015, pp. 1–5.

[6] IST-TONIC. Retrieved February 2017. [Online]. Available: cordis.europa.eu/result/rcn/81333_en.html

[7] CELTIC-ECOSYS. Retrieved February 2017. [Online]. Available: www.celticplus.eu/project-ecosys

[8] T. Rokkas, D. Katsianis, and D. Varoutas, “Techno-economic evaluation of FttC/VDSL and FttH roll-out scenarios: Discounted cash flows and real option valuation,” *Journal of Optical Communications and Networking*, vol. 2, no. 9, pp. 760–771, 2010.

[9] T. Monath, N. Elnegaard, P. Cadro, D. Katsianis, and D. Varoutas, “Economics of fixed broadband access network strategies,” *IEEE Communications Magazine*, vol. 41, no. 9, pp. 132–139, 2003.

[10] S. Verbrugge *et al.*, “Research approach towards the profitability of future FttH business models,” in *Proceedings Telecommunications Network Strategy and Planning Symposium (NETWORKS)*, Warshaw, Poland, June 2011, pp. 1–10.

[11] M. Forzati *et al.*, “Next-generation optical access seamless evolution: Concluding results of the european fp7 project oase,” *Journal of Optical Communications and Networking*, vol. 7, no. 2, pp. 109–123, 2015.

[12] K. Casier, *Techno-Economic Evaluation of a Next Generation Access Network Deployment in a Competitive Setting*. Universiteit Gent, 2009.

[13] C. Antunes, J. Craveirinha, and J. Clímaco, “Planning the evolution to broadband access networks: A multicriteria approach,” *European Journal of Operational Research*, vol. 109, no. 2, pp. 530–540, 1998.

[14] R. Zhao, L. Zhou, and C. Mas Machuca, “Dynamic migration planning towards FttH,” in *Telecommunications Network Strategy and Planning Symposium (NETWORKS)*, Warshaw, Poland, September 2010, pp. 1617–1622.

[15] R. R. Reyes, R. Zhao, and C. M. Machuca, “Advanced dynamic migration planning toward ftth,” *IEEE Communications Magazine*, vol. 52, no. 1, pp. 77–83, 2014.

[16] K. Wang *et al.*, “Migration strategies for fttx solutions based on active optical networks,” *IEEE Communications Magazine*, vol. 54, no. 2, pp. 78–85, 2016.

[17] F. Phillipson, “A cost effective topology migration path towards fibre,” *Lecture Notes on Information Theory Vol*, vol. 2, no. 1, 2014.

[18] F. Phillipson, C. Smit-Rietveld, and P. Verhagen, “Fourth generation broadband delivered by hybrid ftth solutiona techno-economic study,” *Journal of Optical Communications and Networking*, vol. 5, no. 11, pp. 1328–1342, 2013.

[19] T. Rokkas, “Techno-economic analysis of pon architectures for ftth deployments: Comparison between gpon, xgpon and ng-pon2 for a greenfield operator,” in *Telecommunication, Media and Internet Techno-Economics (CTTE), 2015 Conference of*. IEEE, 2015, pp. 1–8.

[20] A. Mason, “Opensolver an open source add-in to solve linear and integer progammes in excel,” in *Operations Research Proceedings 2011*, ser. Operations Research Proceedings, D. Klatte, H.-J. Lathi, and K. Schmedders, Eds. Springer Berlin Heidelberg, 2012, pp. 401–406.

 ISBN: 978-1-61208-544-9