Critical Market Parameters for Viability of Fiber Access Network Business Case

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Abstract – This paper presents the results obtained by techno-economic analysis of the fiber access (FTTH) business model. The analysis determinates a combined influence that major market parameters have on overall viability of FTTH business case. These critical parameters include the geodemographical background of the customer base, adoption of services provided over FTTH network and related additional revenues that can be generated. The analysis is based upon the incumbent's case in Croatia, assuming previous existence of ducts within access network. The results indicate that FTTH business case is profitable in urban areas in ten-year time period, but only in a case the majority of customers subscribe to the services over the new network and simultaneously bring significant amount of additional revenues.

I. INTRODUCTION

Laying of optical fibers in fixed access networks has been significantly practiced during the past decade throughout Europe and in other developed world countries, such as USA, Japan or Korea [1] [2]. Reaching end users with fibers has enabled operators and service providers to offer advanced services in comparison with services provided over still prevailing copper networks. Apart from incumbents and alternative operators, investments in fiber access networks have also been driven by municipalities and public utility operators.

Fiber access networks are commonly designated *Fiber to the "x"* (FTTx), where "x" denotes the nearest point that operator's fibers reach with respect to end user premises (e.g. home, building, curb or cabinet). Derived from the term *Next Generation Networks* (NGN), *Next Generation Access Networks* (NGA), as the term for the access part of NGN, has also been widely used for FTTx networks, especially within the official EU documents [3].

There are several fiber access technologies with related topologies that have become the most influential in the telecom market [4]. ITU-T G.984 group of standard for Gigabit Passive Optical Networks (GPON), as well as its counterpart IEEE 802.3ah standard for Ethernet Passive Optical Networks (EPON), are both suited for the *point-to-multipoint* (P2MP) access network topology. In P2MP fiber networks a single fiber is, by mean of passive optical splitters, extended to multiple fibers that reach end users in final segments of the access network. Contrary to that, in the *point-to-point* (P2P) networks, each user is connected with at least one dedicated fiber. P2P topologies utilize the suitable Ethernet protocol from IEEE 802.3 standard group, depending on the required transmission capacity.

As it is a case with any emerging technology, the fiber access networks are to introduce significant changes in telecom operators' existing business models. Considering the telecom market liberalization process, especially within EU, major challenges are foreseen in the regulatory ecosystem, where regulators are expected to preserve the achieved level of market competitiveness, preventing the introduction of new infrastructure monopoly by incumbents or other vertically integrated operators. In the same time, operators' investments in FTTx networks have appeared to be risky, due to the questionable prospects of users' adoption of advanced services and their willingness to pay an extra sum for them.

This paper describes the techno-economic analysis of investments in fiber access networks, with respect to the critical input parameters, which are the density of customer base, the additional revenues that can be generated by services over fiber networks and the adoption of services by end users. The analysis relies on the incumbent case in Croatia, assuming the incumbent owns and operates a duct network. However, results of the analysis can be generally applied to the similar market situations, including the non-incumbent operator case with smooth access to existing duct infrastructure.

The paper is organized in five chapters. After this introduction, within the second chapter the general overview of related techno-economic analyses of fiber access networks is given. The third chapter specifies the basic technical and market assumptions for the analyzed FTTH business case. Next, in the fourth chapter the description of the business model, built upon assumed FTTH business case, is presented. Finally, the fifth chapter discusses the economic results of the FTTH business model analysis, with concluding remarks regarding the viability of the business case.

II. RELATED TECHNO-ECONOMIC ANALYSES OF FIBER ACCESS NETWORKS

Technical, economic and regulatory aspects of fiber access networks have been extensively investigated during the past several years. In this chapter three examples are referenced, which the work described in this paper is related with.

In [5] authors make general calculations and analyze of the main economic risks for wide-scale deployment of FTTH networks in USA, being the uncertainty regarding the potential revenues that services over fiber access networks can generate. This uncertainty causes the capital intensive infrastructure investments to be very sensitive to customer adoption figures and competitive pressure from other operators with similar FTTH business plans. The authors indicate that FTTH infrastructure competition model with vertically integrated operators is unlikely to be viable and, among others, propose new models with a single set of FTTH infrastructure, commonly used by all operators and service providers.

The study prepared for Dutch telecom market regulator [6], investigates profitability of the FTTH P2P business case for Dutch incumbent and alternative operators, by the method of comparison of the incremental costs for build out of FTTH access network with the incremental revenues that can be obtained from services over such network. While the incumbent's business case becomes profitable under requirement of the minimal incremental ARPU of 13 EUR monthly with the geographical coverage of 60% of country's population, alternative operators' business cases are rather worse, without the possibility to profitably replicate build out of FTTH network. Contrary to that, fiber unbundling and bitstream wholesale products are shown to be economically viable options, enabling alternative operators to compete with the incumbent.

The other study produced for European Competitive Telecommunications Association [7] focuses, among others, on the profitability of FTTH networks in Europe, investigating related business opportunities within six EU countries. The static method applied in the study equals long run incremental costs (LRIC) of build out of FTTH networks with achievable revenues generated. Since the revenues are dependent on a market share, the critical market shares are identified, that make LRIC costs recoverable and particular business model positive. With respect to densities of population in geographical areas, together with regulatory and market circumstances in the countries analyzed, the study shows that both P2P and P2MP FTTH networks are profitable for incumbents, but restricted to the areas with 10-20% of national population, which are mostly dense urban areas. Also, the build out of another FTTH infrastructure by only one alternative operator is generally not profitable or is profitable only in restricted parts of the densest urban areas.

Both analyses [6] and [7] focus on the regulatory segment of FTTH models, investigating if they are generally viable for incumbents and alternative operators, with suggestions for necessary regulatory remedies that should ensure competitiveness of operators. Therefore, the actual periods of return of FTTH investments are not deeply analyzed, as well as their relations to the additional revenues gained by FTTH networks and customer adoption rates. The authors in [5] tackle this issue generally, without detailed calculations.

III. Deployment of Fiber Access Network

This paper gives an overview of the techno-economic analyze of the FTTH deployment model, focusing on the expected payback periods. Also, the impact that additional revenues and customer adoption of services over FTTH networks have on payback periods are analyzed. Instead of applying a generic greenfield approach for the deployment of FTTH networks, the scenario analyzed in this paper deals with an incumbent operator with existing duct network, relying on the incumbent's case in Croatia. However, scenario modifications can easily be introduced in the business model, enabling analyze of FTTH investments in other market environments.

A. Network Topology and Technology

It is assumed the incumbent operator has chosen to build the P2MP FTTH network, utilizing ITU-T G.984 GPON standard. The reason is that P2MP networks require 10-20% lower costs for fiber layout in comparison with P2P topology [7]. Furthermore, GPON technology, with the split-ratio of 32, ensures sufficient bandwidth per customer (up to 75 Mbit/s downstream [1]), suitable for fast broadband services (up to 30 Mbit/s) and simultaneous reception of several high-definition video streams.

B. Geographical Coverage

In order to precisely analyze an influence that different geographic and demographic parameters have on build out of fiber networks, areas to be covered are grouped within four geodemographical clusters (TABLE 1). Each cluster is specified by the dominant type of housing and the range of customer density figures, where each potential customer refers to a single household. It should be noted that given clusters represent only urban and suburban areas, with customer densities larger than 50 per km^2. The actual size of particular cluster and the total number of clusters are derived from the official demographic data for Croatian settlements [8].

TABLE 1 – Geodemographical Clusters

Cluster label	Cluster	Dominant type of housing	Customer density per km^2
G1	Dense urban	Large multi-dwelling	>1.500
G2	Urban	Multi-dwelling	500-1.500
G3	Dense suburban	Multi-dwelling and single-family	200-500
G4	Suburban	Single-family	50-200

Rural areas with lower customer densities are not analyzed, due to different technical parameters that should be considered in the build out of FTTH networks in these areas, in order for corresponding scenarios to be viable (e.g. layout of fibers on poles, instead in ducts). Also, due to the weaker geodemographics, deployment of other broadband technologies that have optimal capacity efficiency in these areas, can be seen as an alternative to FTTH networks. Further discussion on this topic is outside the scope of this paper.

C. Ducts and In-building Infrastructure

The scenario in this paper assumes that underground ducts in the access network already exist and are operated by the incumbent. Also, it is supposed that the duct network reaches all dwellings to be covered and has sufficient capacity for the layout of new fibers, meaning that no additional civil engineering works within the duct network are required. However, “rights of way” fees have to be paid to land owners the ducts stretch on.

For the purpose of calculating the fiber length that is needed for the coverage of targeted clusters, the square geometric model is used (Figure 1). Within the model, each square represents an area of single housing unit. At least one of square’s sides belongs to a road or any other corridor used for guiding of ducts. Duct sections spread from the central aggregation node within the access network, commonly designated as Metro Point of Presence (MPoP).

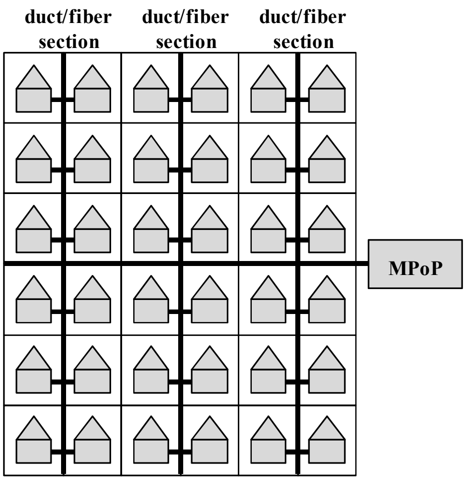

Figure 1 – Square geometric model of duct/fiber network, bold lines represent duct/fiber sections

Considering the P2MP topology, it is assumed that GPON splitters are co-located with distribution frames that enable flexible connectivity among access fiber sections. These installations are placed inside large dwellings or, in case of single family houses, inside outdoor cabinets.

Regarding the build out of final sections of fiber access network inside dwellings, besides labour and material costs as main drivers, it is supposed that there are no any extra costs related to licences that could be required for the rights to enter inside dwellings (e.g. owner’s permission).

D. Services

The adoption or *take-up rate* of customer connections over FTTH network is predicted according to the targeted figures for fast broadband coverage in the period 2011-2020 in EU’s Digital Agenda initiative [9]. This initiative targets the 100% coverage of European households with the fast broadband connections of at least 30 Mbit/s by 2020. Here, for the basic scenario case, it is assumed that the final take-up rate in the ten-year period will be slightly lower, reaching 80% (Figure 2). This is primarily the consequence of local conditions in Croatian market, with continuous lagging behind the average EU’s broadband figures during the period 2001-2010 [10].

Considering services provided over FTTH network that customers are subscribed on, it is supposed that, besides fast broadband services that are used by all customers, a part of customers also uses TV and the telephony services. On average, it is predicted that 2/3 of customers are also subscribed on TV services and 3/4 on telephony services. These shares present the predicted growth in the model, which prediction is based on the recent growth of bundled subscriptions in EU [11].

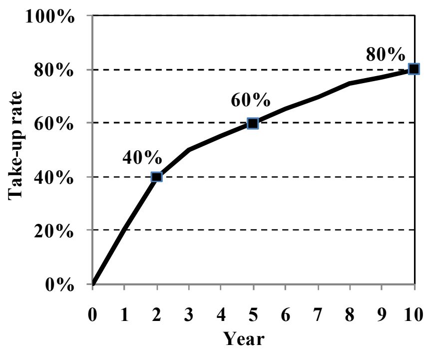

Figure 2 – Take-up rate of FTTH customer connections

Figures for the average bandwidth consumption per customer are based on the declared bit-rates of fast broadband packets and the applied contention rate, according to the current EU market situation [10], with the predicted future growth in the model. In the basic scenario case, it is assumed the average maximum consumed speed for broadband packet is 10 Mbit/s in the starting year, rising to 20 Mbit/s; while contention rate rises from the starting 1:50 towards 1:30, in the ten-year period. Additionally, the average of 10 Mbit/s is calculated if a customer uses TV services. The Figure 3 gives an overview of the average maximum consumed bandwidth per customer, based on the declared bit-rates, including the bandwidth for TV services, applied with the proper service share in customer base. It should be noted that the predicted growth of bandwidth and contention rate figures relate to maximum bandwidth figures which are expected to be consumed by customers, taking into account not only the throughput of the FTTH access lines, but also the throughput of core network available to each customer.

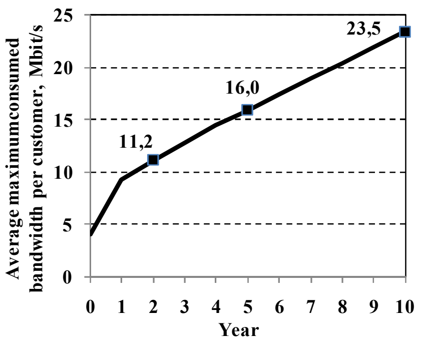

Figure 3 – Average maximum consumed bandwidth per customer (Mbit/s)

As fiber deployment scenario considers the incumbent operator with wide variety of existing services, only additional, incremental revenues generated by services on FTTH network are assumed to be of practical concern for economic calculations in the presented model (the reason behind it is described later within the paper). In order to predict these extra revenues, the recent EU data for general broadband and specific FTTH retail packets were compiled [12]. Finally, for the basic scenario case the average incremental revenues over the projected ten-year period are assumed to match the additional monthly ARPU (average revenue per user) of 8,0 EUR. The stated ARPU figure includes both contributions of additional revenues from fast broadband services (due to the enhanced speed and reliability), as well as the revenues related to the advanced TV services not necessarily suitable for ADSL connections (e.g. high definition TV).

Taking into account the uncertainty of prediction of the parameters related to services, primarily the take-up rate and the incremental revenues, previously given figures represent only the basic case values, which are subject to a sensitivity analysis prior to the final conclusion of the business model viability.

IV. FTTH BUSINESS MODEL

The following chapter gives an overview of the FTTH business model and related technical and economic methods applied for its analysis. Related equipment, installation and maintenance cost values, applied in the model, are not cited in the paper.

A. Relation to Operator's Existing Network and Services

As FTTH business model concerns the incumbent operator case, it is assumed that the operator already runs a complete telecommunication network, serving, among others, customers connected over copper access network. By that, the operator's network already includes aggregation network, backbone core transport network and central service logic for telephony, Internet access and TV services (Figure 4). Additionally, the deployment of FTTH network requires build out of new access network and upgrades within aggregation, core and Internet peering parts of the network (due to the increased capacity that can be utilized over FTTH networks).

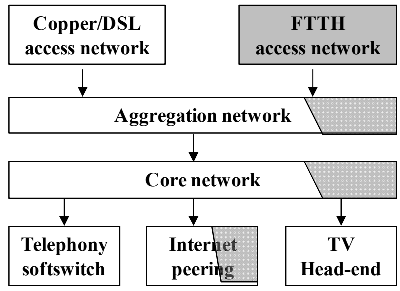

Figure 4 – FTTH model in relation to operator's existing network (new and upgraded network parts are shaded)

In order to accurately analyze the impact the deployment of FTTH network has on overall incumbent's business activities, the model considers, on the cost side, only additional expenses related to the introduction and operation of FTTH network and services. By such approach, the complex, history related calculations with incumbent's legacy network parts and services are avoided. It can be argued that migration of DSL customers to FTTH network might have a neutral or at least not significantly negative effect on overall incumbents' business activities, as additional costs of FTTH investments can be compensated by savings in copper access network costs, due to its lower utilization. In this analysis, the actual savings in the copper network are assumed to be negligible, taking into account that aged copper networks in majority of incumbents' networks have been mostly depreciated and do not require significant maintenance costs.

Similarly, on the revenue side, the FTTH model considers only incremental revenues obtained from services over FTTH network. This increment is calculated against the revenues of all existing services that the incumbent offers within its network, including the services that can be migrated from DSL to FTTH access network (e.g. broadband and TV services).

B. Model Structure

The main modules of the FTTH business model, including their mutual relations, are shown in the Figure 5. The predicted values for cluster types, take-up ratio and service mix are used as inputs towards the cost calculation modules and incremental revenues module. *Fiber infrastructure* module calculates the necessary length of optical fibers as well as their layout and maintenance costs. Similarly, within *In-building infrastructure* module, the corresponding costs for the layout of final fiber sections within the customers' dwellings are considered. Next, *GPON equipment* module takes into account the costs for the central office devices (OLT – optical line termination), passive splitters and customer premises equipment (ONU – optical network unit). In the *Core network* module the upgrade costs for aggregation and core transport networks are calculated. Finally, the resulting values from *Total costs* and *Incremental revenues* modules, together with applied discount rate, serve as inputs for the economic analysis of the business model.

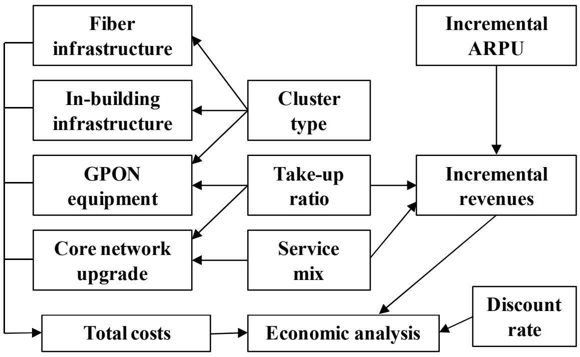

Figure 5 – Structure of FTTH business model

C. Economic Analysis

The economic analysis of the FTTH business model is based on the Cash Flow (CF) method. This method implies the calculation of cash flows as differences of revenues generated and costs incurred within a period of time (usually corresponding to one year). The costs include both operational and capital expenditures. The operational expenditures cover the recurring costs for operation of the network (e.g. lease of international Internet peering links), maintenance and repair of network components, and for provisioning and marketing of services [13]. On the other side, the capital expenditures consist of one-off purchase costs of network components (e.g. GPON equipment, optical fiber), including necessary effort required for their installation.

As FTTH business model is projected over the time period of ten years, future cashflows need to be discounted, in order to consider a time value of money. The assumed value of the discount rate is 15%, considering the higher risk entailed by the deployment of FTTH network, according to the European Commission NGA recommendation [14].

Consequently, in order to properly judge the profitability of the business model and calculate expected payback periods of investments, the Net Present Value (NPV) method is applied. NPV of investment project is a sum of Discounted Cash Flows (DCF) over projected time-period T with discount rate r (1).

$$NPV = \sum_{t=0}^{T} DCF_t = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \quad (1)$$

The payback period considered in this work corresponds to the Discounted Payback Period (DPbP) and equals to a time interval since the beginning of an investment in which a value of NPV reaches zero (2), meaning that the investment has paid off itself and started to generate a profit.

$$NPV_{DPbP} = \sum_{t=0}^{DPbP} DCF_t = 0 \quad (2)$$

V. FTTH Business Model Analysis

In this chapter the results of the FTTH business model analysis are presented. Firstly, the basic scenario case with ten-year investment period is considered, taking into account NPVs for various geodemographic clusters and various take-up rate values. Secondly, the values of incremental ARPU and take-up rate are both varied, conforming to the predefined DPbP values of 5 and 10 years. While the first set of results gives general information of the profitability of FTTH business case in the predicted market conditions, the second one provides more detailed view of an influence the main input parameters have on the overall viability of the FTTH business case, stressing the major risks that may have negative effects on the FTTH project.

A. NPV Analysis in Ten-year Time Frame

NPV calculation at the end of ten-year period was conducted assuming basic scenario values of the key input parameters: for the incremental monthly ARPU 8,0 EUR and for the average bandwidth consumption per customer as per curve shown in the Figure 3. The take-up rate values in final years of the model were varied in the range from 10% to 100%. The actual growths of take-up rates during the period were adapted to the final year's value by a linear scaling of the basic scenario curve from the Figure 2. All four geodemographic clusters were considered (G1-G4).

The Figure 6 shows the NPV curves for the clusters G1-G4 as functions of the take-up rate at the end of the ten-year period. As expected, the final year's NPVs increase with higher take-up rates. However, it is obvious that only for the clusters G1 and G2 NPVs reach positive values, as take-up rates rise above 50% and 80%, respectively. This ensures the viability of the FTTH business case in these urban clusters, in case a major part of customers adopt new services over FTTH networks.

Analyzing the NPV curves for the clusters G3 and G4, (suburban areas), it can be seen that the corresponding business cases are not profitable in the ten-year period, regardless of the take-up rate. Even if 100% of customers adopt new FTTH services, no positive NPV is achieved under specified assumptions.

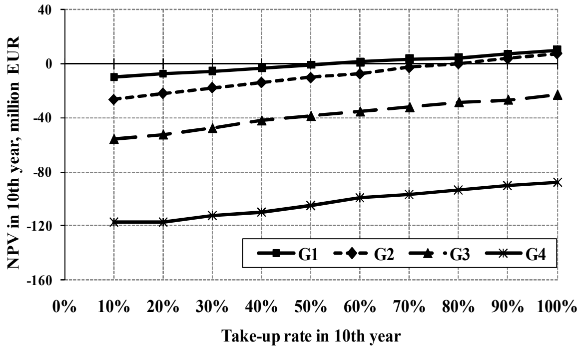

Figure 6 – NPV in final 10th year of business model, as function of take-up rate

In order to further illustrate the NPV functions for the clusters G3 and G4, additional graphs are given, containing NPV developments within ten-year period for the basic scenario case take-up rate value of 80% (Figure 7).

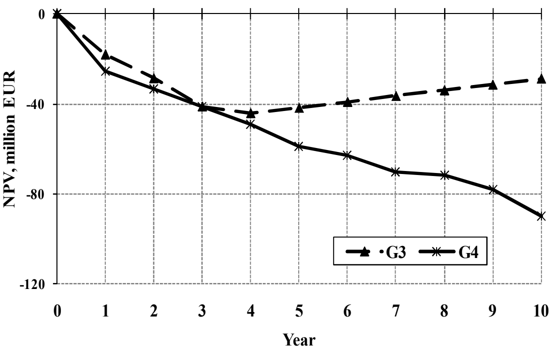

Figure 7 – NPV development within ten-year period, the final take-up rate is 80%, clusters G3 and G4

It can be seen that the NPV curve for the cluster G3 achieves positive growth after the cash-flow turnover point in the fourth year. Furthermore, it can be argued that in some distant time point, after the projected period, the curve reaches x-axis, ensuring profitability for the business case. However, such conclusion cannot be given with existing business model assumptions, due to an increased uncertainty of input parameters future values, outside the given time period. Such uncertainty is caused by expected significant changes in market conditions and services beyond this period.

Simultaneously, looking into the negative growth of the NPV curve for the cluster G4 in the Figure 7, a straightforward conclusion is complete unprofitability of the FTTH business case in low density suburban areas, as even it is not possible to start to recover initial investments.

B. Influence of Main Input Parameters

The graphs in the Figure 8 show dependencies of incremental ARPU values and take-up rates for the given DPbP values of 5 and 10 years. The separate graphs for the clusters G1-G4 are shown, with identical scales on y-axes. Take-up rates on x-axes correspond to the final values in the given DPbP years.

Considering only the curves for the clusters G1 and G2 in the case of ten-year DPbP, with respect to the basic scenario's incremental ARPU of 8,0 EUR and the final take-up rate of 80%, it is obvious that even for lower take up rates, that are still higher than 40%, required incremental ARPUs do not change significantly and remain below 10,0 EUR. Also in cases of the clusters G1 and G2, the differences (in term of ARPU) between DPbP=5 and DPbP=10 curves have maximum of 3,0 EUR for take up rates higher than 40%.

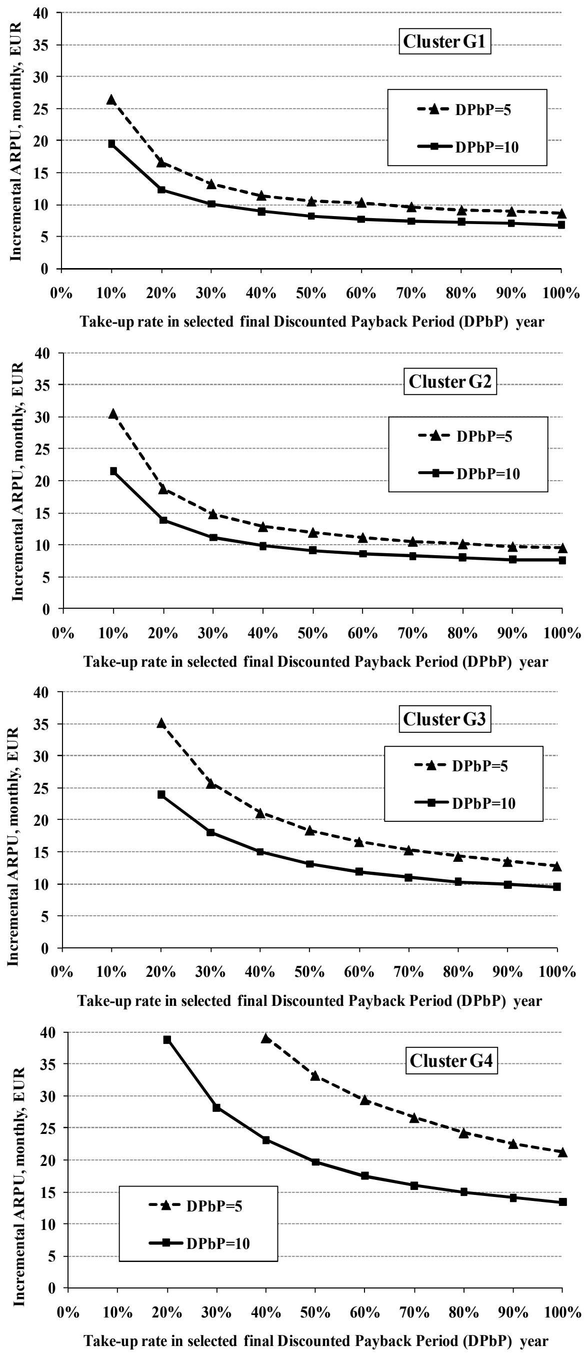

Figure 8 – Incremental monthly ARPU as function of take-up rate, for selected final Discounted Payback Period years (DPbP=5 and DPbP=10) and geodemographic clusters G1-G4

This all indicates that FTTH business case can be profitable in urban areas also in the case the customer adoption is lower than 80%. Furthermore, under more favourable ARPU conditions than initially projected, the profitability can be achieved even before the period of ten years.

Regarding the graphs for the clusters G3 and G4, which business cases are not viable for the basic scenario's ARPU of 8,0 EUR, it can be seen that only increase above this value ensures profitability within the ten-year period. While required ARPU additions have maximum of 4,0 EUR for the take-up rates higher than

60% in the cluster G3, required ARPU additions for the cluster G4 are significantly higher, reaching 8,0 EUR in the case of take-up rate of 70%. Also, analyzing the five-year DPbP curves for the clusters G3 and G4, it is evident that differences to the ten-year DPbP curves are much higher in comparison to the clusters G1 and G2.

Finally, it can be concluded that FTTH business case in dense suburban clusters can become profitable, but under very stringent requirements of high customer adoption and simultaneously incremental ARPUs higher than 8,0 EUR. The business case in other lower density suburban areas is not viable at all, considering that a market situation with nearly 100% customer adoption and incremental ARPU values higher than 13,0 EUR is not realistic.

However, it is very important to note that generally positive FTTH business cases in the clusters G1 and G2 are very sensitive to a decrease of incremental ARPU values. Practically, if incremental ARPU values are decreased below 7,0 EUR monthly, profitability cannot be reached within the ten-year time frame, even for the ideal 100% take-up rate. This fact stresses the importance of additional revenues that should be generated over FTTH access networks, in order for corresponding business models to be viable.

C. Investments per Covered Household

Investigating further the background of bad profitability indicators within the clusters G3 and G4, average investment figures per household covered with FTTH network are compared among the clusters. These investment indicators are calculated by a division of a sum of capital expenses for build out of fiber access network with a number of households that are covered by FTTH network. The capital expenses for build out of fiber access network include the costs for procurement and layout of fibers, construction of in-building final fiber drops, and procurement and installation of GPON equipment and splitters. As the average cost for the cluster G1 is the lowest one, values for other clusters are related to the G1's cost value (Figure 9).

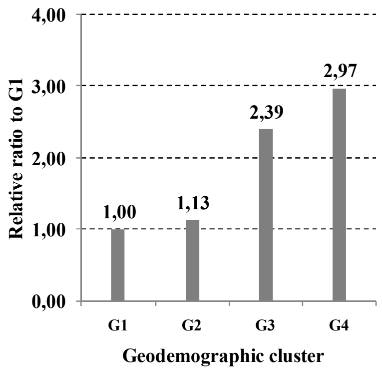

Figure 9 – Relative ratios of investments per household covered with FTTH network, for geodemographic clusters, with respect to investment value for cluster G1

It can be seen that average investment values for the suburban clusters G3 and G4 are twice to three times higher than in the dense urban area cluster G1. This come as a consequence of additional length of access network sections in suburban areas, due to a lower customer density and less multi-dwellings in comparison to urban areas.

VI. CONCLUSION

This paper analyzed the impacts that additional revenues and adoption rate have on a viability of fiber access network (FTTH) business models in urban and suburban areas, focusing on expected payback periods. The model was suited to an incumbent operator with existing duct network in Croatia. A point-to-multipoint access network topology was assumed, with ITU-T G.984 standard (GPON). The economic part of the analysis was performed by applying the Net Present Value (NPV) method.

The results of the analysis indicate that FTTH business case is profitable in densely populated urban areas under relatively modest assumptions of the incremental monthly ARPU of at least 8,0 EUR and customer adoption rate that is higher than 50%. The profitability in this case implies pay-off of initial investments and generate of profit within the ten-year time period.

Less populated suburban areas are much more sensitive to minimal values of incremental revenues and adoption rates than urban areas. In the same ten-year period the FTTH business case is positive only in densely populated suburban areas (above 200 households per km^2), but only in case the incremental ARPU is at least 10,0 EUR and the adoption rate is higher than 70%. The impact that ARPU and adoption rate parameters have in less populated suburban areas (below 200 households per km^2), additionally worsens the business case there, requiring ARPU values to be higher than 13,0 EUR and adoption rate above 80%, in order for profitability to be achieved in the ten-year period.

A further work on this subject should investigate possible external incentives that can ensure the viability of FTTH business case in other areas than urban, in order for all customers to be able to benefit of the advanced services offered over FTTH networks. The other important issue to be analyzed is a way for the introduction of competition among operators in the FTTH services market. Focusing on the wholesaling of incumbents' FTTH network resources, such competition model should find a balance between worse profitability indicators of incumbents (due to a lower retail market share) and benefit of end customers who should be able to choose a service provider from among several operators.

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