Optimal Allocation of State Aid Funds for Deployment of Next Generation Broadband Networks

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Abstract — **This article analyzes a deployment of nationwide Next Generation Access (NGA) networks in Croatia, focusing on a support of state aid funds in cases where deployment cannot be profitably accomplished by operators in the market. The profitability of NGA networks in various geodemographical, technological, revenue and market scenarios is checked by means of incremental cost model. For unprofitable areas, several options for application of state aid funds are proposed, including a deployment of public networks. The proposed state aid options aim to optimize total amount of public funds that are spent, simultaneously fostering the maximum level of competitiveness of the operators in the market.**

Keywords — next generation access networks; techno-economic analysis; state aid; public networks

I. State Aid for Broadband Networks

Ubiquitous availability of access to broadband networks has been recognized as the most important prerequisite for a transition to knowledge based society and economic growth of local communities and whole nations. In European Union (EU), this has been confirmed through the framework strategy Digital Agenda for Europe [1], setting, among others, ambitious targets for broadband coverage till 2020. Achievement of these targets requires introduction of Next Generation Access networks (NGA) on a nationwide scale, with fast broadband access (at least 30 Mbit/s) being available to whole population and ultra-fast broadband access (at least 100 Mbit/s) being available for 50% of population.

EU countries have generally been following Digital Agenda broadband coverage targets, defining their own National Broadband Strategies (NBS) [2]. Croatia, accessing EU in 2013, has already adopted NBS for shorter time horizon till 2015 [3], which is partly compliant with Digital Agenda targets.

Deployment of NGA networks requires significant investments. Actual level of investment is mainly dependent on local geodemographic patterns and considerably increases in scarcely populated rural areas. The other factor determining the level of investment is an ability of re-usage of existing network infrastructure, which particularly relates to cable ducts and poles.

Consequently, deployments of NGA networks are long-term infrastructure investments which do not have straight profitability profiles for operators. The profitability is, besides above mentioned factors, additionally dependent on market demand for services, regulatory conditions, number of competing operators etc.

Numerous countries in EU have already recognized that investments in broadband networks, and particularly in advanced NGA networks, require some kind of public support, in order to achieve NBS targets and utilize social and economic benefits of broadband networks in all parts of a country. Although not necessarily in a form of investment grants, public support in markets is generally designated as *state aid*, relating to formal juristic definitions on national and EU levels. Lately, the rules and best practices for applying of state aid to investments in broadband networks have been listed within EU Guidelines [4].

The main principle of the state aid is a requirement to limit its application only to cases where it is absolutely necessary, which are usually in areas experiencing a lack of investment from operators (so called *white* and, conditionally, *grey* areas). Furthermore, networks utilizing state aid have to be built as open networks, supporting various wholesale products for other operators accessing such networks [5]. The latter requirement indicates the importance of the state aid for a promotion of competitiveness in the telecommunication market, in common with existing EU *ex-ante* regulatory rules.

A. State Aid Models

There are numerous models (or types) of application of the state aid in broadband infrastructure projects. Generally, they differ in a way that formal, organizational and economic relations among public and private partners in a state aid project are settled. Public partners usually correspond to governments, regional or local municipalities, while private partners are most commonly operators in the market. Comprehensive description of various state aid models can be found in [6], while here only three basic models are briefly listed, covering the work described by this article.

A *private model* assumes that an operator, as direct recipient of state aid subsidies, builds and operates a network, as well as permanently retains its ownership. This model usually does not include firm control over beneficiary operator. In a long-term period it can give suboptimal results, with the respect to limitation of competitiveness in the market and higher amount of state aid funds being spent.

Contrary to the private model, a *public model* requires significant involvement of public bodies, which are, as direct state aid beneficiaries, responsible for construction and operation of subsidized networks. The operation is usually limited only to wholesale offers for operators that finally act as service providers in retail markets. Public model generally presents a better option for achieving of long-term social and market objectives, due to the fact that subsidized networks remain in public ownership.

Finally, a *public-private model* takes advantages of both standalone models, combining capabilities of public bodies and operators in investment, build-out and operation phases of subsidized networks. Public-private models are usually realized through joint ventures or public-private partnerships. They offer a possibility of optimal matching of public interest (which is general availability of broadband access), with operators' aim of achieving economic profit.

B. Analysis of State Aid Projects

During the last several years, numerous state aid projects have been conducted within EU countries, initially focusing on basic broadband networks in rural areas and lately dominantly targeting NGA networks [5],[6],[7].

While there exists a significant number of studies and articles that focus on empirical analysis of state aid projects, the volume of work related to general analyses of technical and economic parameters for application of state aid projects is much lower.

Profitability of fiber NGA investments and a need for state aid measures in Germany are discussed within [8]. The article analyzes necessary amount of state aid and proposes three options that can support nationwide deployment of fast broadband networks - subsidization by all customers with higher retail prices, allocation of operator's extra profit from urban areas to investments in unprofitable rural areas, and external investment subsidies.

Social efficiency of broadband access subsidies is analyzed in [9], focusing on economic balance among positive effects for customers, positive effects for alternative operators and potentially negative effects for incumbent operators. The article is focused on the case of unbundling of copper loops in France.

In Croatia, broadband state aid projects are still in nascent phase. A study that generally discusses applicability of state aid measures in Croatia, also proposes several investment models suitable for various regions, depending on a state of existing network infrastructure [10]. A study [11] analyzes profitability parameters of various technical scenarios for deployment of fiber access networks across all parts of Croatia. Detailed techno-economic analysis of municipal fiber access network project for mid-sized town of Krk is presented in [12], including an analysis of applicable state aid models.

This article presents an overview of analysis of profitability of deployment of NGA networks in all regions of Croatia. Where profitability cannot be achieved, solutions for application of state aid measures are proposed. Rather than focusing on formal investment and organizational aspects of state aid measures, the article primarily investigates optimal solutions for allocation of state aid funds, with respect to minimization of necessary amount of state aid, while simultaneously achieving maximum level of competitiveness for all operators in the market.

The article is organized in five chapters. After this introductory chapter, the second chapter gives overview of techno-economic model that is used for analysis of profitability parameters. In the third chapter, results from techno-economic model are presented for various regions of Croatia, assuming networks are deployed by private operators. The fourth chapter analyzes the properties of public networks, built according to the public state aid model. Conclusively, within fifth chapter, optimal model for allocation of public funds within state aid measures is proposed for Croatia, combining public and private state aid models.

II. TECHNO-ECONOMIC MODEL

This chapter gives an overview of techno-economic model that is used for profitability analysis. The outputs of the model are incremental costs, corresponding to similar regulatory long run incremental cost (LRIC) models. Such static approach corresponds to a stable market condition in a future, after all potential transitional effects will diminish (e.g. demand on NGA networks below maximum expected level due to a migration of users from traditional broadband networks). In the same time, the incremental model simplifies profitability analysis, as all relevant network costs can be straightly compared against expected periodical service revenues.

Schematic structure of techno-economic model is given in Fig. 1, following with more detailed descriptions of structure in the subsequent subchapters. It should be noted that, due to space limitations, only the most relevant properties of the techno-economic model are described within the article.

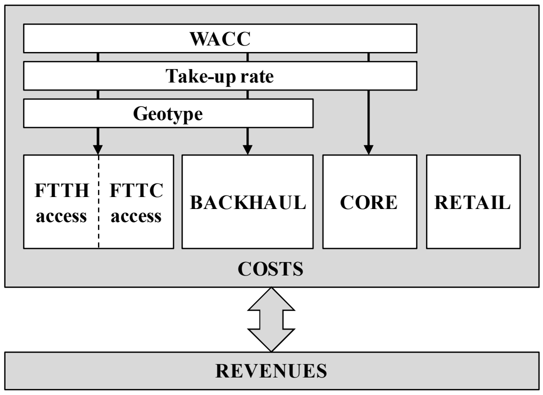

Fig. 1 – Overview of techno-economic model structure

A. Network Segments

The model portions operator's network in four segments, corresponding to their geographic coverage and common cost properties: access, backhaul, core and retail. The core (or backbone) segment is the nationwide network consolidating several main regional nodes, while backhaul (or aggregation) network has a regional scope connecting access segments in settlements with core segment of the network. The retail segment relates to centralized functions that enable offer of services to end customers (service logic, billing, customer relations management etc.).

B. *Access Network*

Among numerous NGA network varieties, the model considers Fiber to the Home (FTTH) and Fiber to the Cabinet (FTTC) networks. The former assumes deployment of dedicated fibers to each customer premise (point-to-point (P2P) topology), while the latter relies on partial re-use of existing segments of copper pairs closest to customer premises (so called drop segments) and deployment of additional nodes (cabinets) at the network side of drop segments, equipped with VDSL access multiplexers (ITU-T G.933.2) and fiber link towards backhaul network. In this way, FTTC networks also support fast broadband connections and are less costly alternative to FTTH networks.

C. *Geotypes*

The model supports 12 different geodemographic patterns, or shortly geotypes, set according to the overall structure of settlements in Croatia [13]. The designations of the geotypes correspond to their characteristics (U1-U4 – urban, S1-S4 – suburban and R1-R4 – rural geotypes) - TABLE I. Population figures, in common with sizes of settlement areas for particular geotype, are the main cost drivers for access and backhaul network segments. Additionally, backhaul segment costs are also driven by average distance of settlements in geotype from main core nodes (higher values in suburban and rural geotypes).

TABLE I – STRUCTURE OF GEOTYPES IN CROATIA

Geotype	Average population of settlement in geotype	Number of settlements in Croatia	Share in total population of Croatia
U1	625.000	1	16,1%
U2	162.500	3	8,8%
U3	62.500	4	5,5%
U4	42.500	2	2,0%
S1	25.000	16	8,8%
S2	11.250	21	5,2%
S3	5.750	51	6,6%
S4	3.000	123	8,1%
R1	1.500	307	10,1%
R2	750	659	10,8%
R3	350	1.446	10,8%
R4	100	3.974	7,2%

D. *Take-up Rate*

Take-up rate denotes the ratio between a number of active customers and total number of constructed customer connections in the access network. Higher take-up rates result with lower costs, which is particularly significant for access and backhaul segments. For the purpose of the work presented in this article, take-up rate was set to 62,5% for all geotypes. It corresponds to the average penetration of broadband in population of 25,0%, which is predicted as the realistic value that can be achieved in Croatia within time frame of several years, considering current penetration values in Croatia and EU by mid-2012 [14]. Furthermore, the assumed high take-up rate value corresponds to a market situation in which all customers have been migrated from traditional broadband networks to NGA networks, which situation is of practical concern to the work presented by this article.

E. *Weighted Average Cost of Capital*

Weighted average cost of capital (WACC) generally comprises an interest rate corresponding to the operator’s cost for borrowing of money for investments in infrastructure and equipment. Additionally, WACC also considers a profit rate that private operators in the market are expected to achieve. In this work, the WACC rate for private operators is set to 10,0%, reflecting average values across several EU countries and all network segments considered [15].

F. *Revenues*

The prediction of future level of revenues that can be generated on NGA networks, in comparison with traditional broadband networks, is quite challenging. Therefore two revenue scenarios are considered, designated as *high ARPU* and *low ARPU* (Average Revenue Per User). The high ARPU scenario predicts larger shift from current revenues on traditional broadband networks in Croatia (primarily ADSL based) - TABLE II. Separate ARPU figures are given for FTTH and FTTC based access networks, corresponding to their throughputs and capabilities to offer advanced services.

TABLE II – ARPU FIGURES IN REVENUE SCENARIOS

Scenario	FTTC	FTTH
High ARPU	150,00 HRK	200,00 HRK
Low ARPU	127,50 HRK	170,00 HRK

III. PROFITABILITY OF NGA NETWORKS

In order to check profitability of deployment of NGA networks by private operators, the previously described model has been applied on all geotypes, with both access network scenarios (FTTH and FTTC), as well as both revenue scenarios being considered.

A. *Competition Scenarios*

For the purpose of modelling competitive structure of the market, three competition scenarios are analyzed, designated as monopolistic, bitstream and unbundled local loop (ULL). They differ in a way particular network segments are shared among operators, the latter two scenarios corresponding to the most common wholesale products available in the telecommunication market.

The monopolistic scenario assumes that only one operator is present in the market, investing in and owning all network segments and being the only provider of retail services. The bitstream scenario corresponds to a situation in which there is a single set of access and backhaul network segments, owned by an infrastructure operator which offers its capacities to other (alternative) operators that operate their own core networks and offer services in the retail market. Finally, in the

ULL scenario infrastructure operator exclusively builds and operates only access network segment and offers corresponding physical capacities to alternative operators (in ULL manner). In the ULL scenario all operators, including infrastructure and alternative operators, have their own backhaul and core networks and offer services in the retail market. Also, it is assumed that in the bitstream and ULL scenarios a single operator has the minimum 20% market share in the retail market.

Considering competition among operators, ULL scenario presents the most desirable situation in which infrastructure competition is maximized, enabling operators to differentiate their retail services at most. Besides this, competition scenario in which all operators build and operate their own networks through all segments, is even more desirable. However, such ultimate scenario is not economically feasible in Croatia, as a duplication of FTTH access network segments is generally not viable for any operator, even in the most densely populated areas [11]. Precisely, such kind of access infrastructure competition is theoretically possible only in urban geotypes if both high take-up rate is assumed (higher than 70%) and full re-usage of existing ducts is possible. However, neither of these two assumptions are taken as practically feasible for the work described in this article. It should be also noted that copper infrastructure in the FTTC scenario is not considered as the candidate for duplication at all, as it constitutes legacy infrastructure owned by an incumbent.

B. Profitability Analysis

Results of profitability analysis of FTTH and FTTC based networks, through all geotypes, competition and revenue scenarios, are shown on graphs in Fig. 2 – Fig. 5. The profitability figures shown correspond to a *profitability gap*, indicating the difference between a sum of all costs and expected revenues. As incremental techno-economic model is applied, the profitability gap is indicated on a monthly basis (shown in logarithmic scale on the graphs), per single settlement in particular geotype and per retail customer. Only positive profitability gap values are shown, indicating that business model for particular geotype and scenario is not commercially viable. The absolute values of profitability gap actually indicate the level of external support (eventually articulated through state aid measures) that is needed for particular business case to become viable. Vice versa, negative values of the profitability gap, indicating profitable business cases (in fact indicating an absence of profitability gap itself), for the sake of clarity of graphs, are not plotted.

Firstly, it should be noted that the low revenue scenario generally weakens the profitability indicators, comparing to the high revenue scenario. This is expected result, as an available gap between revenues and costs decreases. However, FTTH networks are more sensitive to variances in this gap and it can be seen that the number of unprofitable geotypes and competition scenarios significantly increases in case of lower revenues. The main reason for this are higher costs of FTTH access network segment, comparing to FTTC ones.

Comparing the indicators of FTTH and FTTC based networks, it is obvious that profitability of FTTC networks can be maintained in a larger number of geotypes than for FTTH networks. While FTTC networks are profitable in almost all cases in urban and suburban geotypes, FTTH networks' profitability for all competition scenarios can be achieved only in urban geotypes in case of high ARPU scenario, which is already confirmed by previous analyses of FTTH business cases in Croatia [16].

Analyzing the competition scenarios, it can be straightly concluded that profitability gap increases with an increased level of infrastructure competition, i.e. monopolistic scenario has the lowest gap indicators and ULL scenario the highest ones. Consequently, although monopolistic scenario is viable in particular geotypes, it is not viable for bitstream or ULL scenarios in same geotypes. This is especially evident in case of FTTH based networks in the low ARPU scenario, where bitstream and ULL scenarios are not viable in a single geotype, while monopolistic scenario is viable in the three largest urban geotypes.

Deterioration of profitability indicators in more competitive scenarios is caused by a need to maintain alternative operators' business cases. In these cases, network costs increase, due to a poorer utilization of network in self operated network segments and lower influence of economy of scale effects, comparing to the monopolistic scenario in which network capacity is utilized to a maximum. Furthermore, as the number of self-operated network segments increases (in the ULL, comparing to the bitstream scenario), the profitability gap is higher, due to an additional separate network segment (backhaul).

Finally, analyzing the absolute values of profitability gap for a particular geotype among different access network and revenue scenarios (where it is applicable), it can be seen that relative differences in profitability gap values decrease towards low populated rural geotypes (especially R3 and R4). This is primarily caused by high share of backhaul network costs and relatively low share of access network costs within total costs. Furthermore, the influence of backhaul network costs is even more obvious in R3 and R4 geotypes, if profitability gap values for ULL scenarios are compared against monopolistic and bitstream scenarios, as in the latter two scenarios there is a single, fully utilized backhaul.

IV. PUBLIC NETWORKS

The results of the analysis in the previous chapter has shown that an external intervention is needed in unprofitable geotypes, if nationwide NGA broadband coverage is to be achieved. An absolute level of external intervention is indicated by profitability gap figures, quantifying a required amount of public contribution in state aid projects. In this way, the public contribution corresponds to general subsidies to private infrastructure operators that build NGA networks (private state aid model), with a principal aim of closing of operators' profitability gaps.

In this chapter, the public state aid model is discussed, which implies public build-out and public ownership of particular segments of network. Considering its economic properties, the most notable property of the public

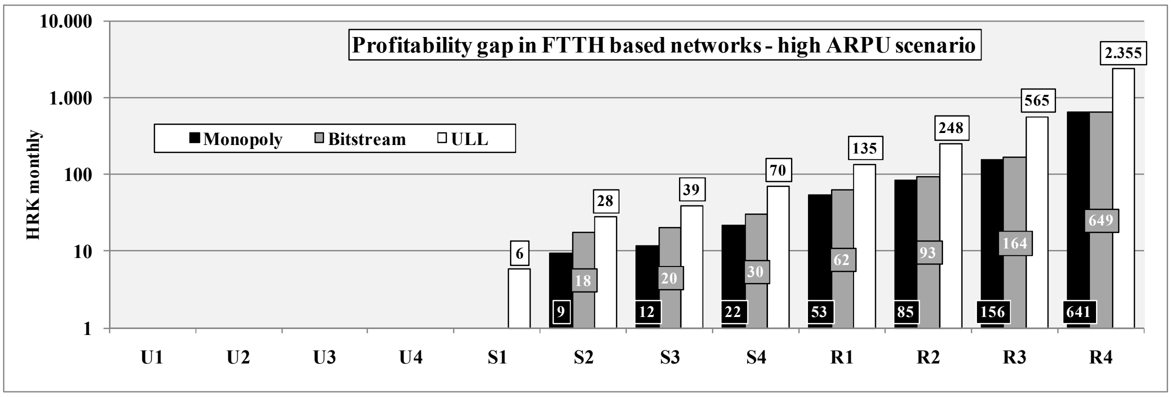

Fig. 2 - Profitability indicators of FTTH based networks, high ARPU scenario

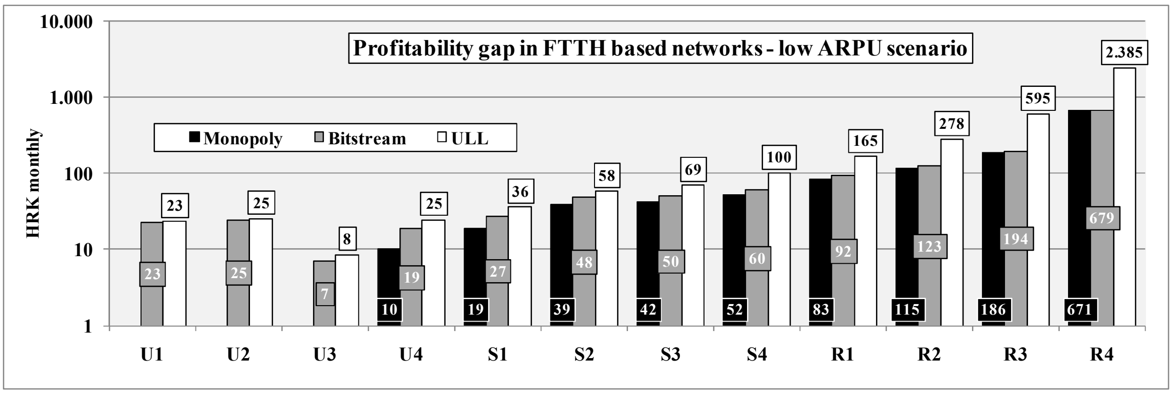

Fig. 3 – Profitability indicators of FTTH based networks, low ARPU scenario

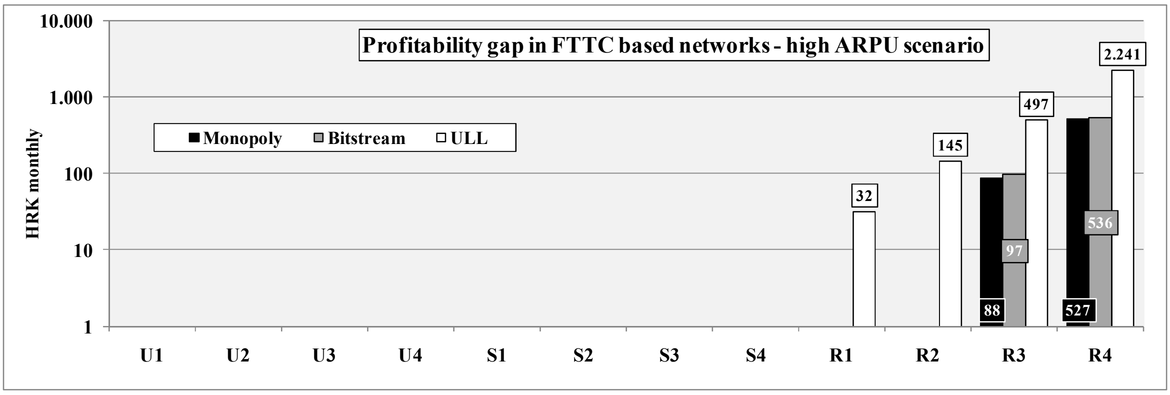

Fig. 4 – Profitability indicators of FTTC based networks, high ARPU scenario

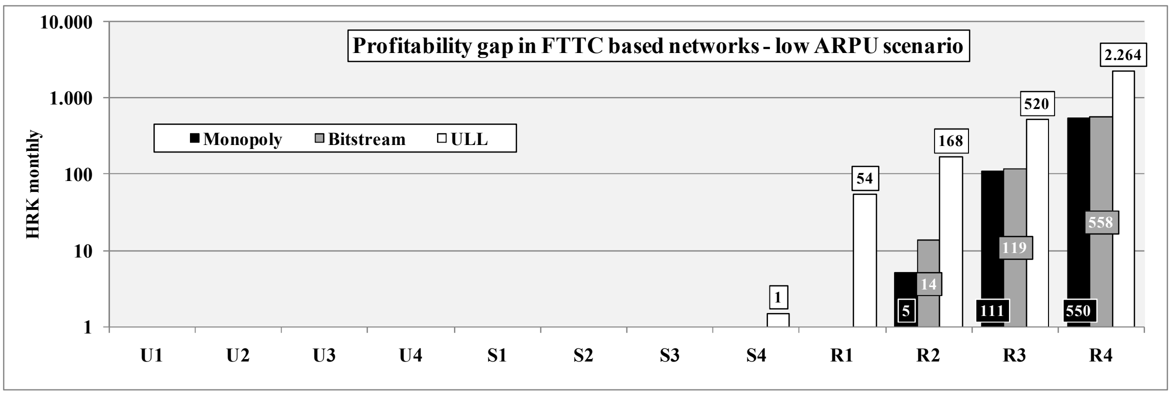

Fig. 5 – Profitability indicators of FTTC based networks, low ARPU scenario

model is a potential to lower WACC value. Such WACC value can reflect only a cost for borrowing of an investment capital (if it is not already available within public budget), and not additionally a cost of profit, which public networks are not expected to achieve.

For the purpose of the work described in this article, a single scenario with public WACC rate of 6,5% is assumed, relating to average yield on government issued bonds in Croatia [17]. Also, it is predicted that only one third of investment funds is borrowed in a capital market and the rest is covered by public budget or EU cohesion policy funds. This finally results with the average WACC rate of 2,2% being applied. The public WACC rate is significantly lower comparing to the assumed private WACC rate of 10,0% and is exercised in this work only with a purpose of comparing of main qualitative characteristics of private and public state aid models, and not with a purpose of reliable prediction of public WACC values. Similarly to the previous chapter, all costs shown in this chapter relate to incremental monthly costs per retail customer.

A. Distribution of Costs per Network Segments

In order to identify the most appropriate segment of the network to be publicly built, an analysis of the relative shares of network segment costs in total network costs in the private state aid model is performed (Fig. 6).

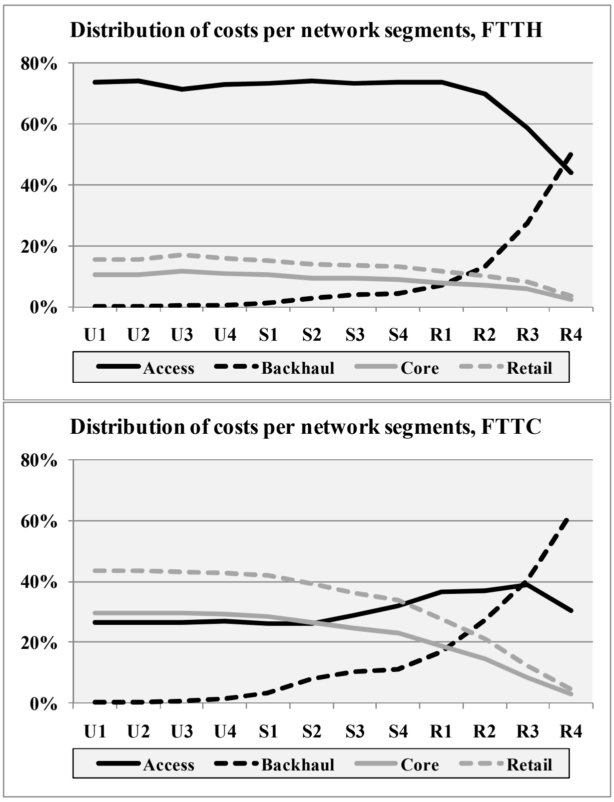

Fig. 6 – Distribution of costs per network segments in total network costs, FTTH and FTTC based networks, ULL scenario

Considering only access and backhaul network segments for which public build-out is practically feasible (and excluding core and retail parts), it is apparent that relative share of access network costs is dominant in urban and suburban geotypes (especially in the case of FTTH access), while share of backhaul costs becomes higher in rural geotypes, particularly in scarcely populated R3 and R4. Taking into account also the profitability results from the previous chapter, the public build-out of network segments with highest cost shares in unprofitable geotypes is foreseen as the most desirable option and is analyzed in subsequent subchapters.

B. Public Fiber Access Network

As FTTH based networks are unprofitable in suburban geotypes and share of access network segment cost is very high in these geotypes (above 70%), the properties of public FTTH networks in suburban geotypes are firstly analyzed. Fig. 7 gives overview of monthly incremental costs per customer for public access network, as well as all other costs a private operator has (for its own operated backhaul, core and retail segments). Costs are compared against profitability threshold (high ARPU scenario assumed), and profitability gap is shown (if exists). Naturally, due to a public character and openness of access networks, only the ULL competition scenario is considered.

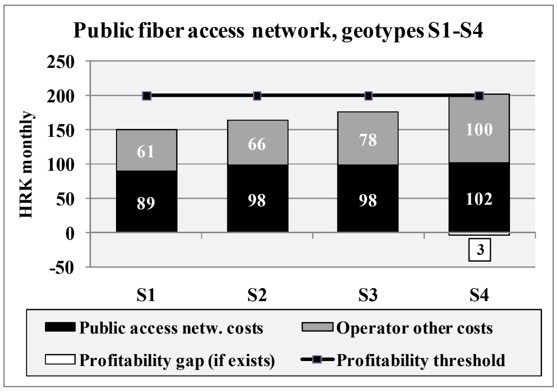

Fig. 7 – Operator costs with public fiber access network, geotypes S1-S4, ULL scenario

It is obvious that publicly funded FTTH access networks enable profitable business cases for private operators in all suburban geotypes, except S4, where a minor profitability gap is present. However, when comparing the costs of public FTTH network with the profitability gap figures in Fig. 2, it is evident that public FTTH networks require higher amount of public funding than it is a case with public subsidies in private state aid models.

C. Public Backhaul Network

In a similar manner, the build-out of public backhaul networks in rural geotypes is analyzed, considering higher shares that backhaul network costs have there, in comparison to other geotypes. In rural geotypes FTTC networks are considered within an access segment, as more economically suitable solution than FTTH networks (due to lower absolute costs).

It is evident that publicly built backhaul networks under the ULL scenario enable profitability for private operators in geotypes R1 and R2, while profitability gaps still exist in geotypes R3 and R4 (Fig. 8). However, overall comparison of involved public funds (covering both costs of public backhaul and additional profitability gap which should be closed by any kind of public subsidization), with corresponding private state aid model in Fig. 4 (ULL scenario), reveals that required public funds in the public backhaul model are lower for all rural geotypes.

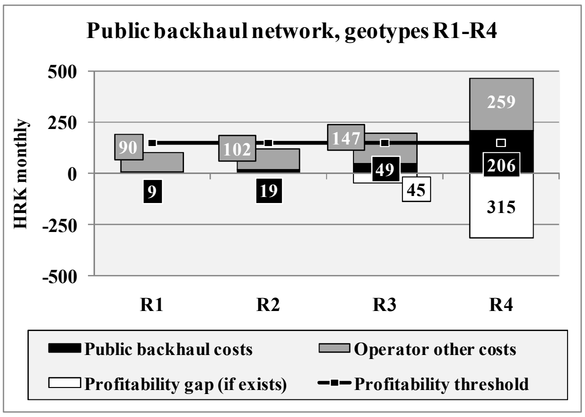

Fig. 8 – Operator costs with public backhaul network, geotypes R1-R4, FTTC based networks, ULL scenario

V. Combining Private and Public Networks

Adding on the analyses of private and public state aid models in the previous chapters, it is evident that state aid measures should balance between an inherent need for minimization of public funds (due to their scarceness) and a necessity to foster the greatest level of infrastructure competition as possible (which corresponds to ULL scenario). This is furthermore emphasized through a choice of optimal access technology. Usually, access solutions with lower costs (which is FTTC in this work) are implemented in low populated areas, optimizing overall network deployment costs.

In this chapter, two options for application of public funds within state aid measures are proposed, comprising both private and public state aid models. The first option aims only to minimize overall public funds, regardless of actual level of competition that can be achieved (i.e. which wholesale products are viable for alternative operators). The second option offers an optimized application of public and private state aid models, ensuring that the highest possible competition level is achieved across all geotypes (i.e. ULL access for all operators). It should be noted that monopolistic scenario is excluded from analysis here, as it does not offer a minimum of competitiveness for operators in the market.

In order to decide an access technology to be implemented, it is assumed that Digital Agenda targets are followed, with FTTH networks (which also support ultra-high broadband access) being implemented in the first 50% of the geotypes (urban and suburban, except S4), and FTTC networks being implemented in the remaining geotypes (S4 and rural).

Only the high ARPU scenario is considered in detail for both state aid options, while properties of the low ARPU scenario are only shortly remarked, as they do not qualitatively change main characteristics of the proposed state aid options.

A. *Minimizing State Aid Funds*

TABLE III presents state aid models that are applied over the geotypes when public funds are to be minimized, together with adjoining profitable wholesale products and necessary public aid amounts on a monthly basis per customer. If a model is public, a segment of the network it relates to is also indicated.

It is obvious that by minimization of state aid public funds, there exist various competition scenarios over geotypes, with competition being limited to bitstream in some geotypes (due to the fact that ULL product requires public funding and bitstream does not within a same geotype, or, in other geotypes where public funding is required anyhow, due to the fact that bitstream requires lower public funding in comparison to ULL). Considering a customer distribution across geotypes, nearly 95% of total aid amount is spent in extremely low populated geotypes R3 and R4. In these geotypes, besides public state aid model for backhaul, additional private state aid model has to be applied in order to close the remaining profitability gaps (see Fig. 8).

The option of minimization of state aid funds does not altogether bring uniform benefits to end customers in all parts of the country. A significant share of customers (41,6%) will potentially experience inferior choice of services, due to a weaker competition among operators in the retail market, as a consequence of unprofitability of ULL wholesale product.

If the low ARPU scenario is considered, a total amount of state aid increases for 18,2%, with private state aid model being applied in six additional geotypes.

TABLE III – Allocation of State Aid – Minimization of Aid Amount

Geotype	Access network	State aid model	Profitable wholesale product	Aid amount (HRK monthly per customer)
U1	FTTH	n/a	ULL	n/a
U2	FTTH	n/a	ULL	n/a
U3	FTTH	n/a	ULL	n/a
U4	FTTH	n/a	ULL	n/a
S1	FTTH	n/a	bitstream	n/a
S2	FTTH	private	bitstream	17,7
S3	FTTH	private	bitstream	20,3
S4	FTTC	n/a	ULL	n/a
R1	FTTC	n/a	bitstream	n/a
R2	FTTC	n/a	bitstream	n/a
R3	FTTC	public (backhaul) and private	ULL	94,0
R4	FTTC	public (backhaul) and private	ULL	521,6
Total aid amount (HRK monthly for all customers):				**53.071.323**

B. *Supporting Maximum Level of Competition*

The second option, supporting a maximum level of competition, i.e. ULL wholesale product through all geotypes, requires public funding to be applied in additional number of geotypes (seven, comparing to four in the first option) - TABLE IV. Therefore, total required amount of state aid is for 9,6% higher than in the first option. Taking into account the customer distribution across geotypes, in the second option a vast majority of public funds is also dedicated for rural geotypes R3 and R4 – 87,1%. Besides these two most scarcely populated geotypes, public backhaul is also the most efficient solution for public funding in the remaining rural geotypes R1 and R2 (but here no additional private models have to be applied to close profitability gaps, as in R3 and R4).

Instead of private state aid model in suburban geotypes in the first option, the second option proposes an application of public-private model for FTTH access networks in suburban geotypes S1, S2 and S3, as the most economically efficient solution (public shares in the public-private models are given in the state aid model column within the brackets). Regardless of the fact that amount of public funding for suburban geotypes is same as in the private model (see Fig. 2), a possibility to partly utilize lower public WACC decreases total costs for deployment of FTTH access network. Additionally, inherent advantages of public-private model enable higher degree of public control over fiber access network, as an essential resource for providing of services to end customers.

The low ARPU scenario requires 19,0% more public funding, with public-private model for access network being also applied in all urban geotypes, and public model for backhaul being additionally applied in the S4 geotype.

TABLE IV – ALLOCATION OF STATE AID - MAXIMIZATION OF COMPETITIVENESS

Geotype	Access network	State aid model	Profitable wholesale product	Aid amount (HRK monthly per customer)
U1	FTTH	n/a	ULL	n/a
U2	FTTH	n/a	ULL	n/a
U3	FTTH	n/a	ULL	n/a
U4	FTTH	n/a	ULL	n/a
S1	FTTH	public (access network - 10%)	ULL	5,8
S2	FTTH	public (access network - 41%)	ULL	27,7
S3	FTTH	public (access network - 59%)	ULL	39,0
S4	FTTC	n/a	ULL	n/a
R1	FTTC	public (backhaul)	ULL	9,3
R2	FTTC	public (backhaul)	ULL	19,1
R3	FTTC	public (backhaul) and private	ULL	94,0
R4	FTTC	public (backhaul) and private	ULL	521,6
Total aid amount (HRK monthly for all customers):				**58.167.151**

VI. CONCLUSION

The article has analyzed a profitability of NGA business cases in Croatia, utilizing FTTH and FTTC access networks. For unprofitable cases, an application of state aid measures is investigated, combining a private model with direct subsidization of operators and a model of public deployment of particular network segments. Two options for allocation of public funds within state aid measures are proposed, the first with a goal of minimizing an overall amount of public funds spent, and the second option maximizing a level of competitiveness among operators, by fostering of physical (unbundled) access to the access network segment. While in the first option the model of direct subsidization of private operators is the most common, the second option gives priority to heavier public involvement in a deployment of networks, with public-private state aid models for fiber access networks in urban and suburban regions and publicly built backhaul networks connecting combined copper and fiber access networks (FTTC) in rural parts of Croatia. Although it is 9,6% more costly than the first option, the second option ensures a better long-term control of public investment through state aid measures, as the critical and the most expensive parts of the network are, at least partly, publicly owned and operated (fiber access networks in urban and suburban parts, and backhaul networks in rural parts).

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