Access Regulatory Remedies in Point-to-Multipoint Fiber Access Networks

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Abstract – This article analyzes access regulatory remedies in fiber access networks, built by operators with significant market power. A focus is put on point-to-multipoint fiber networks. Considering that such topology generally prevents economically viable wide-spread unbundling of fiber loops, comparable to traditional copper loops, other access remedies at local network level have to be imposed by regulators. These remedies include physical access to fibers in terminating sections of access networks and bitstream access at local nodes. The article gives detail overview of technical aspects of these regulatory remedies. The comparison to traditional copper access networks is also given, as well as importance of imposition of adequate fiber migration paths for alternative operators.

I. INTRODUCTION

Traditional fixed access networks, based on copper pairs, have been upgraded to new access network architectures, which are partly or fully based on fibers. Dependent of a final point in access network that fiber reaches with respect to customers, fiber access network are designated with "FTTx" abbreviation, where "x" can be "H" for *Home*, "P" for *Premises*, "B" for *Building*, "C" for *Curb*, "N" for *Node* or "Cab" for *Cabinet*. Except for FTTH and FTTP, the remaining FTTx architectures still contain copper pairs in final parts of access network that are close to customers.

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 [1],[2]. The latter referenced document additionally provides service definition of NGA, specifying NGAs as *networks which are capable of delivering broadband access services with enhanced characteristics, when compared to those provided over already existing networks*.

Comparing to traditional broadband networks, NGA networks support enhanced services, with much higher connection quality and throughputs in both directions. Also, according to the studies [3],[4], deployment of NGA networks results with enhanced economic growth, in terms of faster increase of Gross Domestic Production (GDP) and employment rate indicators.

In 2010 the European Commission has presented *Digital Agenda* strategy, aiming to, among other, significantly increase the availability of NGA networks till year 2020. With respect to broadband speeds, the targets are 100% and 50% coverage of EU household with fast broadband connections (at least 30 Mbit/s) and ultra-fast broadband connections (at least 100 Mbit/s), respectively, in 2020 [5].

In European Union (EU), the electronic communications market has been under strict *ex-ante* regulatory regime since 1990s, aiming to mitigate inherited monopoly of incumbent telephony operators, open the market for other operators and promote service and infrastructure competition, resulting in better availability of electronic communications services for end customers. So called *bottlenecks* in physical communications infrastructure are of great concern for regulation, corresponding to parts of network that cannot be replicated in economically feasible way (e.g. copper loops access infrastructure). Similarly, fiber access infrastructures also present the regulatory bottlenecks, as they cannot be profitably replicated in the majority of EU [6]. Considering this, as well as Digital Agenda targets, European Commission has published dedicated regulatory Recommendation that should foster wide-spread market implementation of NGA connections and services [2].

The deployment of NGA networks has especially advanced in East-Asian countries (e.g. South Korea and Japan), where penetration of households covered with fiber access networks reached more than 35% by mid-2011. In the same time, in EU, the average penetration of fiber covered households was significantly less - 1,9%, with the penetration exceeding 10% in only three EU countries – Lithuania, Sweden and Slovenia. The average EU take-up rate, indicating the share of active fiber connections in total number of fiber covered households, was 17,5% [7].

The Croatian Government has also brought national strategy for NGA networks development, formalized through National Broadband Strategy till year 2015 [8]. The NGA relevant target in the Strategy is 35% national coverage with fast broadband connections (at least 30 Mbit/s) by 2015. By the end of 2011, according to various local industrial sources, it is estimated that maximum of 8% of Croatian household were covered with fiber access networks, with take-up rate of active fiber connections being less than 10%. However, it is expected that majority of these inactive fibers will be commercially offered in the market during 2012, following the implementation of proper NGA regulatory regime imposed to incumbent by Croatian National Regulatory Agency (NRA) – HAKOM.

In this article general technical aspects of FTTH networks are analyzed, together with access regulatory remedies that can be imposed to FTTH network operators. Point-to-multipoint FTTH networks, where limited number of access remedies are practically available, are analyzed in detail, stressing the importance of proper access regulatory regime for market competitiveness in case of such topology.

The article is organized in five chapters. After this introduction, the second chapter provides an overview of most common FTTH architectures with relevant standards. In the third chapter, architectural characteristics of FTTH networks are related with possible access remedies. The fourth chapter analyzes available remedies and their practical feasibility in case of point-to-multipoint FTTH networks. Finally, the article gives conclusion in the last chapter.

II. FTTH Networks Architecture

This chapter gives architectural overview of FTTH networks. Firstly, infrastructural details with respect to the layout of access fibers are discussed. After that, an overview of related network technologies that can be applied on the FTTH networks is given. Terminology used in this chapter has mainly been taken from EU NGA Recommendation [2] and Croatian Ordinance Act relevant to fiber access networks [9].

A. Fiber layout

Similarly to traditional copper access networks, the access fibers spread out from single access network node, which is traditionally designated as Local Node (LN), Local Exchange (LE) or Central Office (CO). With respect to terminology in fiber networks, this node is also called Metro Point of Presence (MPoP). Depending on particular geodemographical conditions, each access node usually covers up to few thousands households, where larger figures are applicable to urban areas. Furthermore, in case of a fiber in the access, due to a higher maximum customer distance from access node, several traditional copper access nodes can be replaced with single fiber MPoP. The MPoP node is equipped to house both passive network parts (e.g. optical distribution frames) and active network parts (e.g. access switches, backbone routers).

The fiber access network is organized in two segments, divided by intermediary Distribution Point (DP) node (Figure 1). The first part of access network, closer to customers, is referred as distribution or drop segment. It aggregates multiple fiber sections from households towards single DP node. There can be several DP nodes belonging to a single MPoP node. The other access network section, closer to MPoP node, is referred as feeder or main segment. It connects DP nodes with MPoP, usually consisting of a single fibers section among these two nodes (although sometimes, due to the redundancy reasons, a number of DPs and single MPoP are linked in ring topology). If flexibility of fiber connections within access networks is required, DP node is equipped with optical distribution frames. Contrary to this, if no flexibility is required, DP node can be a simple aggregation point for fiber cables, placed e.g. within duct hole or at building entrance.

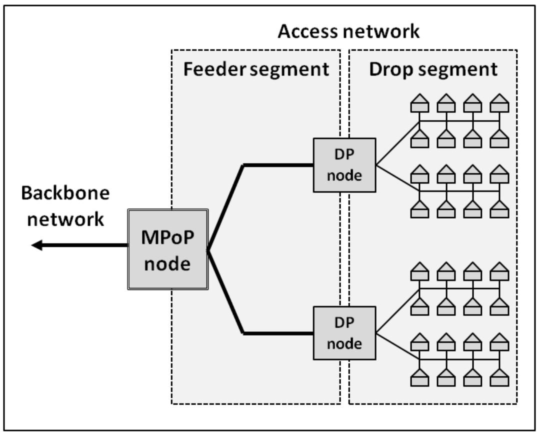

Figure 1 – Fiber access network architecture

The fibers in access network are usually laid in underground duct network. In rural areas fibers are also guided over pole infrastructure, which is generally dependent on urbanistic rules throughout local municipalities.

At least one fiber per household covered is always laid in drop segments of access network. In feeder segments the number of fibers is equal to a sum of all drop segments' fibers or it is less than this sum. The former case corresponds to point-to-point (P2P) access network topology (meaning that each covered household has at least one dedicated fiber that reaches MPoP node), while in the latter case the access network is organized in point-to-multipoint (P2MP) topology, requiring that several households, i.e. end customers, share a single fiber within feeder segment.

B. FTTH technologies

There are several fiber access technologies that have become the most influential in the telecom market [10]. ITU-T G.984 group of standards 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 P2MP access network topology. In P2MP fiber networks a single fiber within feeder segment is, by mean of passive optical splitters, physically portioned in several fibers that reach end users through drop segment. Splitters are usually placed within DP nodes. On the other side, P2P topologies utilize the suitable Ethernet protocol from IEEE 802.3 standard group, depending on the required transmission capacity and maximum distance to customer in access network.

According to the latest market report from mid-2011 [7], nearly 2/3 of FTTH deployments in Europe were based on P2P access topology and Ethernet standard, while the remaining FTTH deployments utilized P2MP topology with related PON technology.

III. Regulation and Access to FTTH Networks

Generally, the regulation of telecommunications market has been focused on encouraging of efficient investments and promoting of competition among market players, i.e. telecom operators and service providers. The power of regulation in many countries has been given to separate national authorities, operationally independent of Governments (commonly referred in EU as National Regulatory Authorities – NRAs). In EU, the regulation policy and rules are defined through *EU Regulatory Framework*, corresponding to a set of formal directives and recommendations to be followed by EU member states and their NRAs. Considering the dominance of traditional copper access networks and incumbent telephony operators in Europe, the significant regulatory effort has been made on providing access to this copper infrastructure for alternative operators. This has resulted, among other, with a number of access remedies (or obligations), imposed usually to incumbent operators, enabling access to incumbents' networks on various infrastructural and service levels [11].

This chapter provides an overview of typical access regulatory remedies that can be imposed to FTTH network operators that are dominant at the market (commonly referred in EU as situation of Significant Market Power – SMP). The relevant technical details concerning these remedies are also analyzed.

A. Reference network architecture

Regulatory remedies covering the access to SMP operator's FTTH networks are related to several reference points within access and backbone network, where interconnection between SMP operator and alternative operators can be established. Here, backbone network corresponds to a part of operator's transport network that links all MPoPs and core part of the network, forming hierarchically organized transport network composed of lower level Regional Nodes (RN) and higher level Core Nodes (CN). Figure 2 gives an overview of reference architecture of SMP operator's FTTH network with interconnection points. The architecture shown is based on the structure of bitstream services, as specified by Body of European Regulators for Electronic Communications (BEREC) [12], extended with network architecture relevant to NGA networks [2],[11].

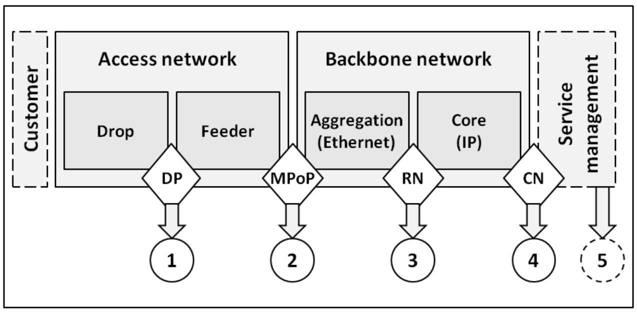

Figure 2 – Reference FTTH network architecture with interconnection points

Depending on a position of interconnection point with respect to network hierarchy level, alternative operator, as an access seeker, is able to cover particular amount of end customers, while simultaneously modelling its own retail service portfolio as allowed by technical capabilities at particular interconnection point chosen. For instance, while positioning of interconnection point hierarchically higher within SMP operator's network enables extended customer coverage, in the same time it offers less flexibility on adjusting of customer services offered, making them highly dependent on SMP operator's network architecture and technology.

Furthermore, in ideal market situation it is expected that alternative operators enter the market on higher hierarchical interconnection levels, optimizing their initial investments, and later advance to lower levels, increasing their investments in own network equipment and infrastructure, while simultaneously decreasing their dependence on SMP operator's network. Such gradual approach on investments is usually referred as *investment ladder* and, especially within EU, presents important postulate of regulation rules [11].

The consequent subchapters describe in detail each reference interconnection point given in Figure 2, together with relevant technical and service capabilities.

B. Access at DP node (1)

Regardless of P2MP or P2P topology deployed, access at DP node enables access to individual fibers in drop segment that directly reach each customer. In regulatory terms, this corresponds to physical access to unbundled fiber sub-loops. This kind of access is in the scope of relevant no.4 market that is generally susceptible to *ex-ante* regulation within EU regulatory framework [2],[13].

While access at this level both enables full physical access to each customer's fiber and is independent of technology applied in SMP operator's FTTH network, it can be economically infeasible for alternative operators. This is practically a case if DP node covers relatively low number of customers, which makes investments in necessary infrastructure for unbundling at DP node unprofitable, especially if DP node is housed within outdoor cabinet. A typical example of low-profile DP node is one that is placed in the vicinity of customer premises, e.g. at the entrance of multi-tenant building.

C. Access at MPoP node (2)

In P2P topologies, all customer fibers reach MPoP node. Therefore it is possible to establish physical access to individual customer fibers at MPoP node. Regulatory, this corresponds to a case of fiber local loop unbundling (LLU), also in the scope of EU *ex-ante* relevant market no.4. Also, such kind of access is comparable to traditional unbundling of copper local loops in DSL networks. Fiber unbundling at MPoP nodes generally presents economically more suitable case comparing to sub-loop unbundling at DP nodes, as MPoP nodes covers much larger areas comparing to DP nodes. Furthermore, in case of copper unbundling in DSL networks, alternative operators have already built necessary unbundling infrastructure at MPoP nodes (which are co-located with copper LE nodes).

Contrary to P2P, in case of P2MP access network topology, fiber unbundling at MPoP node is technically not possible, as single fibers in feeder segments are shared by a number of end customers (reduction of customer fibers from drop segment is performed at DP node, by mean of optical splitters). By this, alternative operators' access at MPoP level is tied to PON technology applied over P2MP fibers and can be achieved only by bitstream service. In EU regulatory terms, the bitstream access is part of relevant market no.5 [13]. Considering PON technology, bitstream access is performed at the backbone port of Optical Line Termination (OLT) node, utilizing Layer 2 network protocol (e.g. Ethernet).

It should be also noted that access to fibers at DP and MPoP nodes can be combined with access to duct space in both drop and feeder segments of access network. In that case it is expected from alternative operators to lay necessary fibers in ducts within access network. Furthermore, EU regulatory framework even states that existence of competitively efficient access to duct space can preclude a need for access to fibers in FTTH networks [2]. However, this is rarely true, as SMP operators' control over duct infrastructure and insufficient space within ducts usually give to SMP operators a competitive advantage over other operators.

D. Access at RN (3)

Access to individual customer at Regional Node level can be achieved only by bitstream access (relevant market no.5), similarly to traditional bitstream access in DSL networks. As majority of incumbent (SMP) operators have already upgraded their aggregation networks with Ethernet protocol, the interconnection point at this level usually corresponds to an interface on Ethernet aggregation switches. The access at this level is also referred as Ethernet level bitstream [12].

E. Access at CN (4)

Core Nodes are placed higher in network hierarchy and, considering national coverage, there are usually only several Core Nodes. Therefore, considering a small number of interconnection points and relatively high customer coverage that can be achieved with single core interconnection point, this bitstream access option requires low investments from alternative operators. However, it gives to alternative operators limited flexibility for differentiation of their retail services comparing to SMP operator's ones.

Core network usually operates on IP protocol, so interconnection is achieved on IP router's interface, therefore designating this bitstream option as IP level bitstream [12]. The fiber IP bitstream access is technically equivalent to DSL network's IP bitstream.

F. Simple resale (5)

By *simple resale* is considered a business model in which alternative operators only resale SMP operator's retail services. Alternative operators even do not own a network infrastructure. The services resold are technically identical to SMP operator's ones. Simple resale model is sometimes treated as type of bitstream service, but is generally not regulated by EU NRAs.

IV. ACCESS REGULATION IN P2MP FTTH NETWORKS

P2P FTTH access networks generally offer more flexibility with respect to the implementation of network technology (Ethernet) and options for alternative operators' physical access to deployed fibers. This also increases a number of available access remedies that can be imposed to SMP operators, therefore facilitating regulatory process.

When comparing investments costs of P2P and P2MP networks per household covered, the cost of P2P network is on average 10% higher than P2MP one, where both passive network infrastructure (e.g. fibers, duct space) and active network equipment at MPoP node are considered [6].

P2P networks have been twice more frequently built in Europe during past few years, comparing to P2MP networks (with respect to number of households covered). Furthermore, P2P topologies have been more common to greenfield projects, i.e. to fiber networks not built by incumbents with traditional copper networks [7].

However, in many cases local market conditions and incumbents' strategies have resulted with P2MP networks being built. These typically included following cases:

- insufficient space in existing ducts in access network (e.g. occupied by copper pairs), which is usually combined with inadequate topology of ducts, that lacks proper intermediary points for fiber DP nodes (duct holes, street cabinets); finally limiting amount of fibers that can be laid (less than one per household covered),
- optimization of investment costs, as P2MP networks are less expensive than P2P networks, including active network equipment,
- incumbents' reluctance to allow access to its fiber network to other operators, opting to build P2MP network which in practice limit physical access by alternative operators, binding them to use bitstream options with less flexibility of retail services.

The remaining part of this chapter analyzes in detail available access regulatory remedies that can enhance competition in case SMP operator's FTTH network is built in P2MP topology. The remedies include physical fiber access at location of splitters and bitstream access at OLT node level. Bitstream accesses at Ethernet and IP levels are as well available remedies in FTTH networks, but are not discussed here, as these bitstream options are technically equivalent to ones in case of DSL networks. This also relates to limited flexibility of alternative operators to model their FTTH retail services at Ethernet and IP bitstream levels, in comparison to SMP operator's retail services.

A. Access at splitters

Splitters within P2MP network are placed at DP nodes, presenting a physical point where number of customer fibers from drop segment are reduced by ratio *n:1* (splitting ratio, the most common values of *n* practically used are 32 or 64). Depending on the access network architecture, DP node can be placed closer to customers or closer to MPoP node, therefore altering the number of customers covered by DP node. Also there are practical cases when splitting is performed in multiple stages (or cascades), and DP node relevant for this access remedy is considered to be the one that houses the last cascade of splitters, located closest to the customers.

Considering this access remedy, alternative operators are able to establish access to terminating sections of fibers at DP node by interconnection of their own feeder fibers in Optical Distribution Frame (ODF). Also alternative operators have to install own ODFs and splitters (usually leasing a part of SMP operator's space at DP node), and OLT and backbone switch (SW) at MPoP or similar local node (Figure 3 – network parts belonging to alternative operator are marked with *(2)*). Alternative operators even have a possibility to deploy P2P network (if there is sufficient duct or fiber capacity in the feeder available).

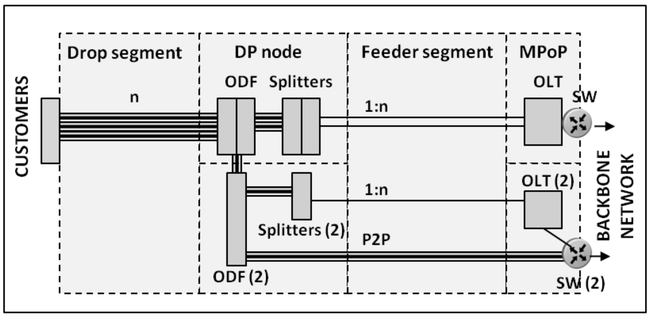

Figure 3 – Access to P2MP FTTH network at DP (splitters) node

The main advantage of the splitters access option is possibility for alternative operators to establish physical access to drop segment fibers, which part of the FTTH network presents the major economic bottleneck for competitive FTTH deployments [2]. On the other side, alternative operators have to make considerable investments in the feeder and backbone parts of the network, which promotes infrastructural competition among operators in the part of the networks where it is generally economically viable.

However, following constraints in practice can prevent full implementation of this access option:

- splitter nodes are placed in the vicinity of end customers (e.g. within multi-tenant buildings), which, due to a low number of customers covered by single splitter node, eliminates economic viability of access (taking into account both the costs of necessary equipment at splitter nodes and the length of feeder fibers),
- splitting is performed in multiple stages (cascades), where the last splitter cascade is placed in the vicinity of end customers, also resulting with economically infeasible access,
- insufficient space or inadequate housing conditions for alternative operators' equipment at DP nodes, requiring significant investments in node infrastructure (either by SMP operator or access operators), which can decrease the overall profitability of this access option for alternative operators.

Conclusively, in order for splitter access to be both economically and technically viable option in the market, P2MP access networks have to be carefully planned in advance, with respect to relative position and customer coverage of DP nodes. A sufficient space at DP nodes has to be ensured for equipment housing (both for SMP and access operators). This is especially important if DP nodes are housed in outdoor cabinets. As it is practically more difficult to introduce any subsequent modifications in already built fiber networks, NRAs should find an optimal way of imposing of these planning rules prior to the construction of new P2MP networks.

B. Bitstream access at OLT level

When physical access at DP (splitters) node is not feasible for any reason, including poor economic prospects of this option for alternative operators, it is important for NRAs to impose access option at the next available level in the network, which is bitstream access at OLT level at MPoP node (Figure 4).

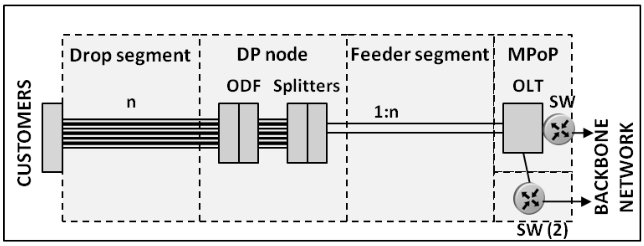

Figure 4 – Access to P2MP FTTH network – OLT level bitstream

Although bitstream services generally offer to alternative operators less flexibility when designing own retail services, this primarily relates to bitstream services on higher network levels (Ethernet and IP level), where alternative operators do not have control over access network parameters. However, in case of OLT level bitstream, interconnection to SMP operator's network is realized at local level MPoP node, where it is technically possible to set corresponding parameters of individual customer access fibers (e.g. maximum throughput, number of virtual channels for multiple services like voice or video, etc.). This is practically performed by changing of parameters of OLT node for individual customer within particular PON splitting group.

OLT level bitstream also presents a suitable access substitute for physical fiber unbundling at MPoP nodes, that is not supported in P2MP network topology. With respect to alternative operators that have already been unbundling copper loops for DSL services in local nodes, this type of bitstream access presents the most suitable migration path towards fiber networks and corresponding services, especially if physical access at splitters node is not available or is economically unattractive. This is also important with respect to preserving of previous investments of alternative operators in copper unbundling (e.g. in room space at local node, equipment racks, backbone switches, backbone links), as generally MPoP nodes are co-located with copper LEs.

In P2MP networks, in case bitstream access at OLT level would not be available (together with access at splitters node), operators using physical copper unbundling would have to use bitstream services at higher levels (Ethernet and IP), when migrating to fiber networks. Considering main postulates of regulation and specifically fostering of infrastructure competition, such step would imply weakening of these postulates and practical descent on the investment ladder.

Therefore, imposition of regulated access at OLT level by NRAs presents very important remedy for smooth migration path towards NGA network for alternative operators, particularly in case of poor prospects of physical access at splitter level.

V. Conclusion

The article analyzed the technical capabilities of regulated access options in FTTH networks, with focus on P2MP topology. Comparing to traditional physical and bitstream access options in DSL networks, introduction of FTTH networks has resulted with additional access option that is concentrated on technical possibility of physical fiber access at DP node. Particularly in P2MP topologies of FTTH networks, due to an access fiber organization and PON technology considerations, a number of available access options is limited. This primarily relates to unavailability of physical fiber access at local node level, therefore implicating a need for introduction of P2MP specific bitstream access at PON OLTs at local nodes. In case physical access at splitters (DP) node level is not available or is not economically viable, OLT level bitstream presents a sutiable substitute for fiber unbundling at local node. This is especially true when existing operators that have deployed copper unbundling facilities in local nodes are planning to migrate their customers to FTTH networks. Such smooth migration path, with OLT level bitstream, retains alternative operators' position on investment ladder and excludes regression to Ethernet and IP level bitstreams.

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