Operators view of the FTTH/Mobile fiber network convergence

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ABSTRACT

Currently, most operators are developing two separate fiber access networks: FTTH and Mobile, with its own rules of designing, cables dimensioning, redundancy etc. 5G at its later stage of development will enforce the aggregation of these two fiber networks in different planes that means technical aspects, regulators, security etc. The paper deals with these elements in order to predict different scenarios of future convergence and taking into account the operators perspective, for whom such issues as competition, security, technological compatibility, costs, etc. are of key importance.

Keywords: Fiber To The Home, Fiber Mobile Network, Network Convergence, 5G, New Radio

1. INTRODUCTION

Network convergence \cite{1}, understood as the coexistence of different services such as telephony, video and data transmission within a single network, is not a new phenomenon. In the past, before the first phase of convergence, each type of service required a separate infrastructure or protocols. Nowadays, both individual and business customers or institutions can enjoy the whole package of services through one type of media and we owe it to the first phase of convergence that has already taken place. Further, more profound convergence is a must and results from the rapidly growing demand for bandwidth and cut to measure quality services (URLLC, mMTC, eMMB) \cite{2}, energy savings \cite{3} and other factors related to the development of 5G networks. It can be assumed that the convergence process, leading to a fully convergent network, will include both physical infrastructure and software platforms. The physical infrastructure will be consolidated and the same network resources will be used to provide both fixed and mobile services. Virtualization and softwarization \cite{4} of the network will continue, allowing the application to run both on a centralized and distributed level. The paper addresses a number of issues of importance to the network operator in relation to the convergence of fiber-based physical infrastructure, in particular the different scenarios for the creation of a fully converged fiber network, the sharing of FTTH and mobile networks, the prospects for the use of SDM technology \cite{5},\cite{6} and fiber network maintenance issues exploring both opportunities and risks.

2. CONVERGED FIBER INFRASTRUCTURE

Although the modern backbone networks are dominated by fiber optics, access networks are characterized by a great diversity in the transmission medium that means: DSL, HFC or radio are still in use, apart from fibers. Other than fiber optic media are, of course, gradually being replaced by fiber optic, but this is a process that is spread out over time and its advancement varies greatly between countries. There are countries in Europe favoring of optical fiber that have almost abandoned traditional mediums, but many of them still rely on that media in access. For instance, the fiber optic network deployed in Spain is the widest in Europe with more than 33.3 million access points, covering more than 75\% of the population \cite{7}, and on the other hand the network in UK is not very advanced \cite{8}.

However, even purely fiber-optic networks, supporting groups of Mobile or Fixed services, are by a certain degree of differentiated, what is a result of different requirements for these networks. The division into fiber optic Mobile network and FTTH is particularly visible.\textsuperscript{--} Fig1. The differences concern both the set of elements that make up the network (fiber, connector, splitter, CEX/CEM, WDM), network scaling and general topologies (P2P, P2MP, star, bus).

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Merging of such diverse networks into a single converged network is a challenge for the operator because it involves costs, loss of services risk, etc. As a rule, such network reconstruction also takes into account the growing needs for infrastructure resources generated by 5G, so one can speak rather of an upgrade that increases network capacity. Such an increase in capacity can be generated on the basis of classical as well as new technologies. One of the candidates on the new, emerging technology is SDM [5],[6].

It is important for the operator to gradually incur the costs of convergence, in correlation with service revenues. Since there are different ways of getting the converged 5G fiber network, the choice of the optimal route becomes a key issue.

The following paragraphs will discuss some of the issues related to the development of that convergent network, which seem important to the authors of this paper.

2.1 Different Pathways to Convergent Fiber Infrastructure

Taking into account the way towards 5G fiber architecture, diverse scenarios of fibre network deployment like Mobile first FTTH later, FTTH first Mobile later as well as Mobile and FTTH in parallel are investigated. Each of these three scenarios has its pros and cons. The advantage of the first scenario (Mobile links first, embark FTTH later) is optimization spending for Mobile. The disadvantages of the scenario are the white spots in FTTH deployment, that means areas uncovered with the network, and scaling of cables for Mobile not compliant with FTTH requirements. The next scenario (FTTH first, Mobile later) means that cables are scaled according to FTTH requirements. The third scenario, most expensive in the early stage of network upgrade, assumes building the fibre network both for FTTH and Mobile, and in practice is associated with planning of dedicated fibre modules (tubes, micro-modules) for particular application.

However, deployment roadmaps of FTTH and Mobile network do not match, in neither time nor space and Mobile footprint largely exceeds FTTH footprint in most EU countries. For example, in France FTTH and Mobil coverage is very different - Figure 2.
Associated with introduction of 5G network densification will mostly to happen in metropolitan areas where FTTH is available. That is why Mobile over FTTH seems to be a good example of convergence that case.

2.2 Collocation of FTTH and Mobile Infrastructure

Undoubtedly, separate FTTH and Mobile networks will operate for some time in a transition period, while the number of points of contact and collocations between them will gradually increase. This applies both to the FTTH and Mobile networks of one operator and the networks of multiple operators. Therefore, we can speak of network sharing. The determination of the way of Mobile and FTTH infrastructure sharing must be preceded by the analysis of the technical feasibility and at least current and forecast density of the Mobile sites and FTTH customers. The sharing of network resources between different operators and the network densification associated with the multiplication of new cell sites will result in a radical increase of network collocation points. Different collocation scenarios are possible. To some extent, they have already been trained within one domain network in a number of countries where the regulator requires access of many operators to FTTH network, as well as when taking over FTTH networks of small local operators. However, the scale of the collocation phenomenon will be much greater in the case of aggregated 5G FTTH/Mobile networks. There are several possible collocation scenarios:

- Collocation of site meant as location of additional cabinets next to each other,
- Collocation of shared fibre infrastructure within a single cabinet or chamber,
- Collocation at a single terminal at the individual fibre level.

A good example of infrastructure collocation forced by the regulator can be the multi-operator cabinets shown in Figure 3.
Each of these scenarios has its own advantages and disadvantages that will be briefly discussed. In scenario 1, location of additional outdoor cabinets requires additional real estate, which is costly and in urban environment very difficult due to aesthetic or architecture reasons. It is much easier to implement such a scenario in a rural environment. In scenario 2, the physical infrastructure of different operators is placed in the same cabinet or chamber. Such a solution is much cheaper and simpler than the first one, but in turn carries risks related to maintenance and security, i.e. when operator A maintenance crew access the cabinet, they will have the access to fibre resources of operator B or C. In such a situation, a cabinet with a special construction with one common space and separate safety spaces for each of the operators is a sure solution. The latter solution is a bit more expensive, but on the other hand, it does not require additional real estate like in scenario 1. Additionally, areas separated for individual operators can be added like blocks as the network grows. Scenario 3 refers to sharing last meters of ODN, and assumes providing a shared by several operators multiport terminal enabling feeding individual homes or RRU’s backhaul links in legacy RAN. Usually for fast connection a pre-connectorized drop cables are used.

Beside of described above schemes of sharing, other arrangements are also possible like electricity suppliers, AC equipment, floor space or even active equipment sharing. A different dimension of infrastructure sharing emerges when considering fibre sharing that can take place in time, space and spectrum. PON by definition provide sharing of the fibre between many end users. This full sharing scheme, combined with scenario 3, provide the ODN necessary to deliver fronthaul links to C-RAN architectures as has been tell in before sections.

2.3 Single-Domain Network Heterogeneity

Although it is assumed that a given type networks, e.g. FTTH, for ILEC operators are homogeneous in terms of construction, scaling, redundancy etc., this assumption is not always true. This is due to market processes that have taken place in recent years. It has quite often happened that fiber optic networks of small operators or networks, built by municipalities, were taken over by larger market players and included in the uniform infrastructure of a given operator. Although there are general principles for the design of such networks, including e.g. requirements for the type of fiber, the budget for attenuation or the scaling of fiber, there may be significant differences in details. Often cost-saving considerations have led to a reduction in the number of back-up fibers or the insertion of passive elements with poorer performance into the network. There were also situations when the budgets of attenuation were being constructed, the margins for aging were given up. Although such networks can work smoothly in case of classical technologies, e.g. G-PON, but transition to the use of wide spectrum (XGS-PON) and WDM may reveal their weakness. The same applies to redundant fibres. The assumption that we have at our disposal e.g. 30% of fibers capacity, because when building a network such redundancy was planned, may turn out to be false in the case of such networks. Table 1 shows a list of parameters that may differ between networks of different operators, built on the basis of the same standard.
Tab 1. Diversification of PON networks of different FTTH operators in Poland.

| Fiber type          | G.652, G.657 |
|---------------------|--------------|
| Total split ratio   | 1:32, 1:64   |
| No of split stages  | 1, 2, 3      |
| Extra fibers in feeder section | 0%-30% |
| Extra fibers in drop section | 0%-70% |
| Attenuation budget (ageing margin) | 0-3dB |

**2.4 SDM as an Option**

Given the growing, due to the introduction of 5G, demand for fibers and given the spatial constraints within the existing infrastructure, SDM technology is becoming very attractive to operators [5]. Fig 4 illustrates three possible approaches to SDMs.

![Spatial Modes](image)

**Fig 4. Space Division Multiplexing Fibers**

The basic idea behind Space Division Multiplexing (SDM) is that if one can define N distinct spatial channels within a single fibre, then the overall fibre capacity can be increased N-fold, or at least close to N-fold when any signal degradation mechanisms/mitigation strategies are taken into account. Where N is the number of additional guided modes for optical communication. Multicore Fibre (MCF), Few Modes Fibre (FMF) and the combination of both, FM-MCF are nowadays the most relevant fibre designs for SDM developments.

With SDM, every additional core or mode provided could serve a single fronthaul link of RAN avoiding the use of WDM implementations, or in order to be a resource efficient solution, TWDM-PON based in CWDM could be used. The fixed services of FTTH could use an independent core or mode and the coexistence of mobile network and FTTH would be transparent between them.

Systemic introduction of SDM technology based on MCF is an attractive solution for a telecommunications operator due to its low cost and simplicity. However, operators must be guided in their decisions by the tough demands of the market and competition. For them, reliability, compatibility with their own infrastructure and with the solutions of other vendors are of fundamental importance. Given the reliability, it is difficult now to confirm that SDM MCF-based solutions are fully prepared for mass deployment. Some elements, especially those located at nodal points (fan-in/out), still do not have proven reliability in the full range of temperatures or mechanical exposures. It is probably a matter of time to get such confirmation, but at the moment a responsible operator cannot turn a blind eye to it.

The SMF are connected in field conditions by means of splicing machines and this is a common practice, thanks to which the installation costs are low. The connection of MCF to each other now requires bit more expensive splicing machines. But, the main problem is to connect MCF with SMF that requires fan-in/outs, which are expensive and not so easy to deal.
As regards the mutual compatibility of MCFs by different vendors, it should be noted that there are no formal standards yet allowing suppliers to adapt their products to certain specifications. Moreover, the number of suppliers is very limited and what they propose is rather a prototype. Finally, it seems not easy the inventory of the MCF connections.

FMF are also not fully compatible with SMF, but maintenance and repair issues are simpler than for MCF. FMF equipment and methods for connecting and fault repairing of SMF can be used, but its SDM technology is less mature than MCF.

From the point of view of compatibility with existing infrastructure and maintenance operations, the most convenient SDM solution would be fiber bundle composed of physically independent fibres. However, this solution does not increase significantly the fibres density factor, which is very important for compaction of telecommunications infrastructure, as does the MCF fibre.

2.5 Converged Fiber Network Maintenance

The purpose of fiber optic networks maintenance, whether FTTH or Mobile, is to control the state of the network during its operation to ensure an adequate level of service. Maintenance includes various activities carried out during the prevention and repair of network and usually these are surveillance, testing and control containing functions of fiber identification, fiber loss or deterioration detection, fault location and confirmation of fiber condition [10].

Maintenance functions can be performed by technical staff or automatically using external measuring devices (for instance OTDR) or using built-in transmission system functionalities. Currently there is a tendency to automate maintenance functions and use built-in system functionalities rather than create separate monitoring systems.

Due to the specificities of each fiber-optic network (FTTH and Mobile) and the different SLA conditions, varies maintenance schemes apply. Technical staff carrying out maintenance of FTTH versus Mobile also have different responsibilities. The convergence of the two networks will also require the development of appropriate procedures, the merging of technical teams and, in general, the harmonization of rules for maintaining a single infrastructure, that is an organizational challenge for the operator.

3 CONCLUSIONS

The second phase of telecommunications networks convergence, driven by the development of 5G technology, is becoming a reality. The convergence includes both physical network resources and software infrastructure.

This paper provides an overview of selected topics that telecommunication operators should take into account entering the path towards a fully convergent fiber optic infrastructure, including both FTTH and Mobile networks.

ACKNOWLEDGEMENTS

This work is supported by the H2020 EU-funded project BlueSPACE (grant no 762055).

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