

Evaluation of FTTx Access Network Migration for IPTV Services

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Abstract—Fixed network operators (FNOs) are seeking to upgrade their existing infrastructure with better investment strategies. For this reason, migration of the existing technologies into new and high income generating technologies is of paramount importance for FNOs. However, even though the end-users have the infrastructure support to receive better services such as HD IPTV, FNOs are not willing to upgrade the status of their existing services to end-users most of the time due to possibility of service disruptions. In this paper, we study a case study and propose Fiber-to-the-X (FTTx) migration strategy where subscribers with ADSL2+ connectivity can be migrated to VDSL2 technology via the proposed methodology that analyses the real operator data and acts based on the proposed criteria. After proposed mitigation study studied in this paper, HD IPTV service has been successfully offered to the end-users that have the potential to have upgraded services thanks to their potential infrastructure capabilities.

Index Terms—network planning, IPTV, FTTx, broadband, services.

I. INTRODUCTION

xDSL-based broadband services have long been provided by service providers. Although services such as fiber-based Passive optical network (PON)/Gigabit-capable Passive Optical Networks (GPON) or Ethernet passive optical network (EPON) are more popular, Digital Subscriber Line (DSL) technologies and Digital Subscriber Line Access Multiplexer (DSLAM) equipments are still being used frequently in vast majority of operators [1]. One of the main reasons for this situation is the fact that it is not feasible for Fixed Networks Operators (FNOs) to make optical line termination (OLT) re-investments on locations where they have already invested in DSLAM technology. At the same time, the excavation of many historical sites and streets for the installation of the fiber network is not approved by the municipalities and local authorities. Due to such reasons, xDSL technologies are still being vastly used as of today.

Asymmetric Digital Subscriber Line (ADSL) and Very High Speed Digital Subscriber Line (VDSL) are currently the most widely used technologies for end users. Their theoretical performance comparisons are given in Fig. 1 [2]. This figure shows the available bandwidth that ADSL2+ and VDSL2 technologies can provide based on the distance between the end-user modem and DSLAM. At the same time, ADSL2+ theoretically cannot provide speed exceeding 24 Mbps for all distances. As observed from the comparisons when the distance increases, the data rates of both technologies drops

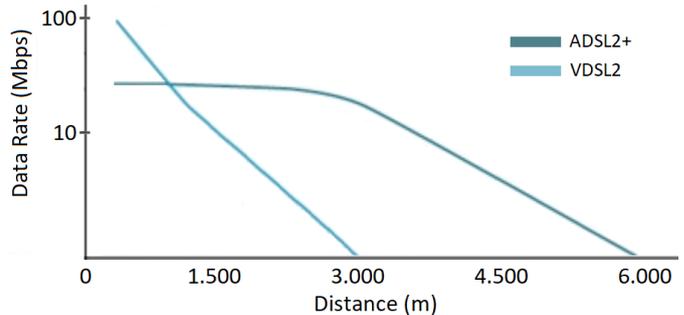


Fig. 1: Comparison of the theoretic performances of VDSL2 and ADSL2+ changing with distance [2].

down. As the distance increases more, the VDSL signal is getting weaker quickly, while the ADSL signal cannot reach to further distances. However, the theoretical study of Fig. 1 is not well reflecting the numerical results in practice. Copper cables with different levels of noise, as well as long periods of deployments, can cause DSL service to be offered at lower distances inside operator networks. This is in fact what is observed by FNOs. The VDSL signal can also be more sensitive than the ADSL signal and may be more negatively affected by noise [3]. The most important aspect of migrating from ADSL technology to VDSL technology are the reduction of interference together with usage of different features such as vectoring [4] and positive contribution to value added services such as Internet Protocol television (IPTV). ITU's document [5] specifies the key performance indicator (KPI) values that operators need to provide for their IPTV subscribers. Features such as high Signal-to-Noise Ratio (SNR) values and high bandwidth capacity are important for viewing High Definition (HD) channels. Therefore, our focus is on migration issues specifically focusing on upgrading IPTV services offered to end-users.

A. Related Works

There are various works in the literature that investigates migration options for operators [6], [7], [8], [9], [10], [11], [12], [13], [14]. In [6], a cost-revenue modelling is presented for dynamic migration strategy of Fiber-to-the-X (FTTx) for FNOs. The cost estimation solutions, techno-economic analyses and deployment opportunities for hybrid Fiber to the Cabinet (FTTC)/VDSL is presented in [7]. Broadband forum

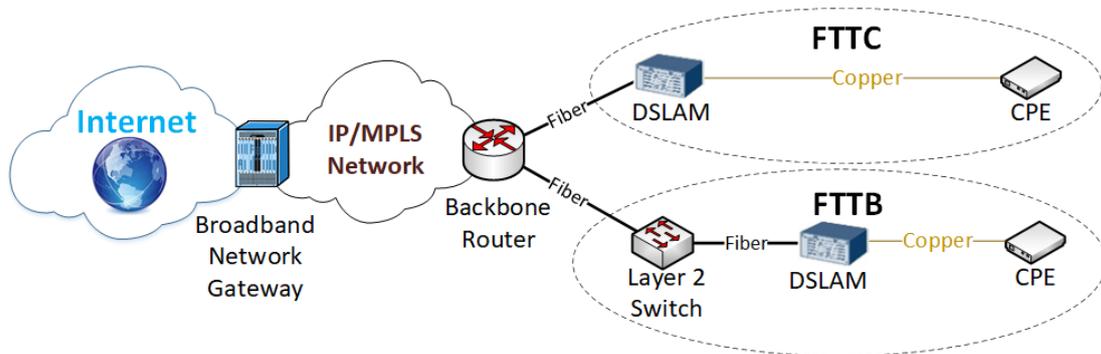


Fig. 2: Deployment architectures of the evaluated FTTC and FTTB systems.

has published a technical report describing network evolution scenarios for service providers' access network migration [8]. The suitable characteristics of access lines for various DSL types are explained in [9]. In [10], a study to compare different FTTx architectures in terms of investments, power consumption and delivered bandwidth is presented. In another study, the migration strategy of integrated fixed FTTx and mobile networks is evaluated [14]. A review for the techno-economic implications of FTTx network deployment in a rural environment of Spain based on regulatory frameworks is studied in [11]. Some performance enhancing techniques that can be applicable to only VDSL based among different DSL access network are presented in [12], [13].

B. Our contributions

In this paper, we study FTTx network migration scenario where subscribers with ADSL2+ connectivity can be migrated to VDSL2 technology using the proposed methodology. The aim is concentrated on IPTV services and how it is influenced by migration options in a real operator network setting. A benefit of the studied method is that subscribers using IPTV over ADSL and receiving SD broadcasts have now access to higher bandwidth HD IPTV services without major service disruptions after the VDSL migration. We have also outlined some of the encountered challenges and limitations during the migration process and the possible utilized solutions to avoid them. The rest of the paper is organized as follows: Section II discusses about FTTx architecture and the corresponding connectivity options. Section III proposes a case study for FTTx network migration planning and strategy for operators and relevant KPIs for the considered case study. Section IV gives the results of analysis. Finally, Section V gives out conclusions.

II. FTTX ARCHITECTURE

Fig. II shows the deployment architectures of the evaluated FTTC and Fiber to the Building (FTTB) systems. FTTC systems are large chassis systems. They are set up at certain rental points or outdoor cabins as well as on the pavements when allowances are granted by municipalities. Because they are close to Central office (CO) points, they are directly connected to a backbone router with the fiber cable. On the other hand, FTTB systems are inter-connected with fiber using a Layer-2

(L2) switch because they are small chassis devices that can be deployed under the building. The copper circuit distances of the subscribers connected to FTTx systems are short, and these copper circuits are less worn out than copper circuits in FTTC systems because they are located inside the buildings. Many FTTB systems under the building are aggregated in an L2 switch and connected to the L2 switch backbone router. The backbone router enables the Broadband Network Gateway (BNG) to communicate to a separate VLAN for each DSLAM via an IP/MPLS network. Subscriber processing related to accounting, authorization operations are done via BNG to allow Internet access for subscribers.

Customer Premises Equipment (CPE) equipments are now designed to include more than one DSL technologies. In Fig. II's topology, subscribers usually buy CPE equipment from the service provider. Therefore, new CPE equipments are capable of supporting both ADSL2+ and VDSL2 technologies. Over time, subscribers may replace their CPE equipment due to various problems. However, for old subscribers, ADSL2+ service may continue to be provided without checking evolving infrastructures' compatibility with VDSL2 technologies. At the same time, the upgrade of these subscribers to VDSL2 is not desired by the service providers due to probability of service discontinuity or existence of potential problems with the existing tariffs. Therefore, there can be situations where some subscribers are not upgraded despite the existence infrastructure support. However, this strategy may result subscribers to churn due to availability of new and advanced services offered by other FNOs. In this paper, we concentrate on determining the potential subscribers that can receive high quality IPTV services since their infrastructure can support and their tariffs are eligible to receive these new advanced services. Together with the KPIs and corresponding criteria defined in this study, subscribers with infrastructure support can now be subject to migration process, i.e. from ADSL2+ to VDSL2 technology without service interruption risks.

In Fig. 3, the communication between the network elements and the systems used for network and subscriber management are shown as a general diagram. In this figure, there is one customer relationship management (CRM) server at the top. CRM servers are generally used for business purposes such as keeping the status of the tariffs purchased by the sub-

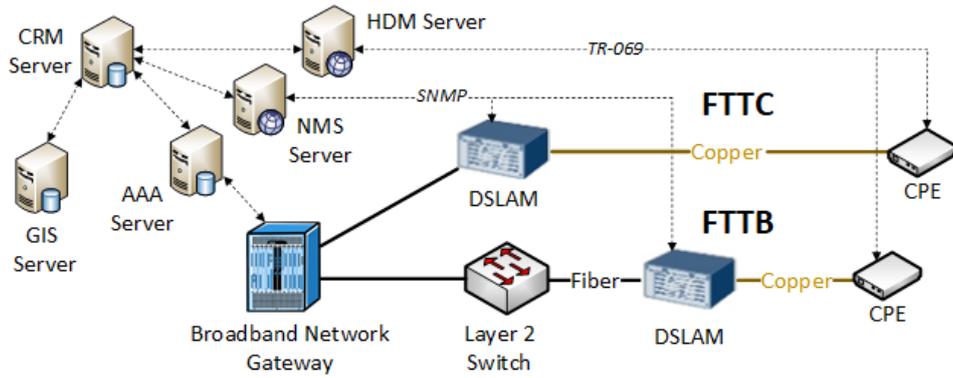


Fig. 3: The systems used for the migration process and their integration structure.

scriber, subscription application/cancellation processes, billing processes as well upsell. The CRM server also communicates with Network Management Server (NMS) servers via web services so that the subscriber service configuration can be automatically applied to the DSLAM port when a subscription order is requested. After the subscriber application is initialized, the new subscriber configuration process is transmitted to the NMS server by the CRM server via web services. The NMS server performs the new subscriber definition on a Simple network management protocol (SNMP)-based device. In this way, manual configuration is not performed by FNO and the configurable removal processes are triggered by the CRM server and then deleted from DSLAM. During this time, the CRM server is also interacting with an Authentication, Authorization and Accounting (AAA) server. The Uplink (UL) and Downlink (DL) speed quota information of subscribers according to their tariffs are also configured on DSLAM via NMS and also set on the BNG via AAA. In this way, even if the speed limit on the DSLAM side has been removed by mistake, the subscriber will not be able to use a DL higher than the speed quota set on the BNG.

CRM and Home Device Manager (HDM) servers communicate with each other via web services. The modem configuration information of the subscriber is transmitted from the CRM server to HDM and configuration information is processed to the CPE or modem via HDM. Hence, new subscriber or subscriber with ongoing reboot processing on modem, will automatically provide configuration information. At the same time, some KPIs held on the modem are periodically collected by HDM. The CRM server is also interacting with Geographic Information System (GIS) server. The purpose of interaction with GIS is that in case subscribers demand to purchase DSL service for the first time, or in case they want to upgrade their ADSL service to VDSL, they can get VDSL service based on the distance. This distance between their building and nearby FTTx node is extracted from GIS server.

III. FTTx NETWORK MIGRATION PLANNING AND STRATEGY FOR OPERATORS: A CASE STUDY

In this section, we present the network migration strategy for FNOs in a case study using the KPIs obtained from the network infrastructure.

A. A Strategy for Selecting FTTx Access Lines for Migration

For selecting the FTTx access lines for migration process, we have collected some of the KPIs related to the existing DSL lines of the network from different sources. Some of them are collected from data stored on the DSLAM by using the SNMP protocol and some parts are collected from the TR-069 [15] compliant HDM management systems with direct connection to CPE. Fig. 3 shows the data collection process for the considered subscribers and the connection of the network equipments that are used for data collection and analysis.

In general, the attainable net-data-rate (β) in VDSL2 systems is calculated in [16] as,

$$\beta = \left(\sum_{s \in S} \left[\log_2(1 + 10^{(SNR_{dB,s} - \lambda_{dB} - \gamma_{dB})}) \right] \right) \cdot 4kbp_s, \quad (1)$$

where s denotes a subcarrier index from the set S of subcarriers actually used in a particular transmission direction; $SNR_{dB,s}$ denotes the SNR value in dB on subcarrier s ; λ dB denotes the SNR gap in dB and it is a system parameter that depends on the used modulation and coding scheme, (e.g., for quadrature amplitude modulation (QAM) and without coding it is approximately equal to 9.75 dB); γ dB is the target SNR noise margin in dB and it is a configurable system parameter, which is usually selected to be between 6 and 9 dB. As shown in (1) the β value can be calculated accurately if and only if

TABLE I
KPIs AND CORRESPONDING CRITERIAS USED FOR THE RANKING OF FTTx ACCESS LINES

Description of the Collected KPI	Criteria
Actual Download Speed (Mbps) ^a	≥ 6 Mbps
Actual Upload Speed (Mbps) ^a	$\geq 0,6$ Mbps
Attainable Download Speed (Mbps) ^a	≥ 8 Mbps
Attainable Upload Speed (Mbps) ^a	$\geq 0,8$ Mbps
Modem Type ^a	VDSL2 Capable
Download SNR Rate (dB) ^b	$\geq 8,00$ dB
Upload SNR Rate (dB) ^b	$\geq 8,00$ dB
Distance to the FTTx Node (meters) ^c	≤ 500 m.

^a From HDM Server

^b From NMS Server

^c From GIS server

the SNR values can be reported over all subcarriers that are able to load bits.

Table I shows the list of KPIs collected from systems as well as the corresponding criterias used for our proposed methodology to select the subscribers that need to be migrated from ADSL2+ connectivity to VDSL2. Six of the KPIs are collected from HDM server. These KPI values have been continuously calculated by the CPE (or modem) and are taken from modems by the HDM server via the TR-069 protocol. Two KPIs represent the values that are calculated by DSLAM devices for each port. These are collected from the NMS servers. One KPI is the distance of CPE to the FTTH node to which it is connected, and this value is taken from a GIS server with inventory information where marking is done over the map. Subscribers that have VDSL2 modems and can get VDSL service without making any additional investments on the DSLAM side may be subject to migration process according to the criteria specified in Table I. For selection of the best parameters, the criterion proposed in this paper are firstly applied to 1000 test subscribers at different time intervals and marked as the best practice for other migrations.

B. Observed Challenges and Solutions

After the migration, we have observed several problems. The number of subscribers affected by these problems is one percent of all subscribers that have migrated. Some of the encountered problems are summarized as follows: **i) Modem re-synchronization problem:** It has been observed that some of the subscribers who have been migrated by the system did not switched off their modem for more than six months. In the case of modems that have not been restarted for a long time, the re-synchronization problem has been observed. For the solution of the problem, the DSL handshake process has been performed several times. Hence, modem devices are rebooted manually to fix the problem. The subscribers were not able to use the services as long as they have experienced this re-synchronization problem. **ii) DSLAM Port problem:** The same DSLAM card can produce both ADSL2 + and VDSL2 signals. During migration process, the configuration defined in the port is deleted and the VDSL2 configuration is assigned to the port. However, it was observed that the corresponding DSLAM port was not functioning after this new configuration. In this case, the problem is solved by transferring the subscriber's DSL circuit to a different DSLAM port. **iii) State of copper lines:** Copper lines that were established in the network copper goes back to almost twenty years or more since their initial installation by the FNO. Hence, the probability to have increased external noise of cables under the ground has increased due to both aging conditions of the cables and the development of the cities and the re-urbanization that has been continuing throughout years. At the same time, due to malfunctions occurring during the years and the repair points, many additional end-points of the cables are present. The losses that can be caused by these additional points cannot be predicted. The ADSL signal has lower frequency of operation, functions properly and the cable state has no effect on these frequencies. On the other hand, the

higher frequency of VDSL2 signal has been greatly affected by the problems associated with aging of the additional points and cables. As a solution, for those subscriber's DSL circuits, reparations are made at the repair points.

C. Migration Process

First of all, subscribers must be informed and approval is needed for starting the migration process. This is also subject to a regulatory requirements as the service type of the subscriber changes after migration process is finalized. In our case, notification to subscribers is provided by short message service (SMS). At the same time, the migration process is performed at certain times which are appropriate such that it does not affect the billing and invoicing processes of subscribers. A javascript application runs for the selected subscribers on the CRM server. Javascript app is simply canceling the subscribers' ADSL2 + subscription in a very short period of time, and subscribes them again as a VDSL2 subscription. In this way, the definitions on the DSLAMs, AAA and the modem are automatically deleted (instead of manual work), so that VDSL2 is reconfigured. The average duration of interruption in subscribers was around five minutes during this period. For any reason, if the migration process is not succeeded for any subscribers, the same process is rolled back and previously given old service is continued to be provided. In this case, those selected but not migrated subscribers were left to be migrated in later migration cycle.

Table II shows statistics for the number of users during our migration process. It basically shows the numbers for subscribers's current tariff constraints, the number of subscribers that can have the potential upgradable infrastructure, the number of subscribers who meet the criteria, and the number of subscribers that are going to be migrated into the HD IPTV service.

IV. ANALYSIS RESULTS OF MIGRATION PROCESS

The comparisons of KPIs before and after the migration studies are shown in Fig. 4 and Fig. 5. Fig. 4 mainly shows the average values collected for actual and attainable KPIs of download and upload speed before and after the migration whereas Fig. 5 shows the average values collected for SNR DL and SNR UL KPIs after migration process. SNR values reflect the noise level that can be tolerated by the access line. Hence, higher results in better observed speeds. Therefore, HD IPTV broadcast, which is more sensitive to noise, can be offered to subscribers under the new situation. After this conversion work, HD IPTV service has become available to the subscribers. We can observe that at the end of the

TABLE II
STATISTICS FOR NUMBER OF SUBSCRIBERS FOR
MIGRATION

Description	User Number
Subscribers Tariffs (Download/Upload)(Kbps)	16.384/801
# of all users that has the upgradable infrastructure	399.962
# of users who meet the proposed ranking criterion	114.061
# of migrated users (eligible for HD IPTV service)	8.317

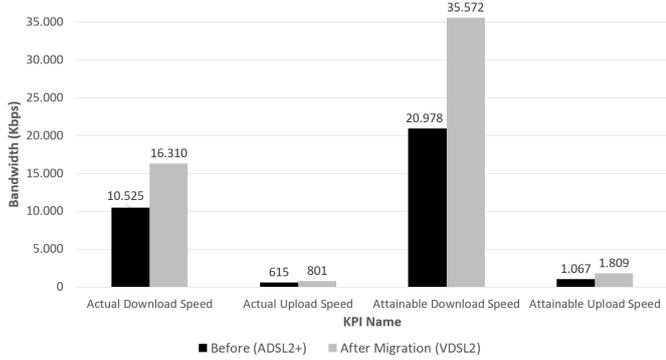


Fig. 4: Average values collected for actual and attainable KPIs of download and upload speed before and after the migration.

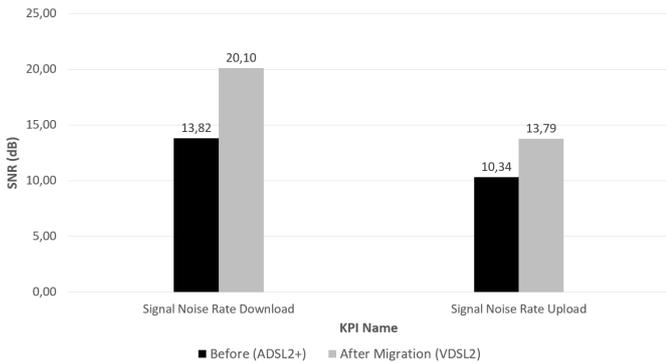


Fig. 5: Average values collected for SNR Download and SNR Upload KPIs after migration process.

migration process, the average DL SNR of subscribers has increased from 13.82 to 20.10. The UL SNR of subscribers has also increased from 10.34 to 13.79. After the migration, we observe that the subscribers' average SNR has also increased. Therefore, HD IPTV broadcast, which is more sensitive to noise, can be offered to subscribers under the new situation.

We can also observe that the average actual DL speed of subscribers (that is observed in real-time) has increased from 10,525 Mbps to 16,310 Mbps. The attainable DL speed of subscribers (that is the theoretical speed) has also increased from 20,978 Mbps to 35,572 Mbps. Hence, after the migration, we observe that the subscribers get the speed in accordance with their subscribed tariffs or packages. On the other hand, the actual DL speed can also be higher than 16,310 Mbps. However, due to upper limit exposed on maximum DL speed on DSLAM port for the considered subscribers with the same tariffs, we have not observed higher speed values. At the same time, the subscribers were able to reach to speeds that are suitable to their tariffs. Similar observations are also possible with UL speeds. In summary, after this mitigation study proposed in this paper, HD IPTV service has been offered to the subscribers that have the potential to be upgraded.

V. CONCLUSIONS

In this paper, we investigated FTTx migration process in case there exists adequate infrastructure support and the

required access distance between CPE and DSLAM. We focus on subscribers that are using the old access types and cannot access the value added services such as IPTV for HD even though their tariffs can be eligible for new and advanced access types. Together with the mitigation methodology and the criteria described in this paper, the migration process has been performed with minimum encountered problems over the migrated subscribers over real-world subscribers of FNO. Hence, together with the increase in the SNR level in the presented migration strategy, the access lines of subscribers have been able to resist a higher level of noise and access to HD IPTV services. Finally, we have also outlined some of the encountered challenges and potential solutions that have been used during the execution stage of the proposed FTTx migration process.

VI. ACKNOWLEDGEMENTS

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