Optimization of FTTH network in Kosovo through the implementation of GPON architecture and analysis of the cost of the implementation

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Abstract — Having regard to the fact that existing access networks in Kosovo are mainly based on copper wires, the access networks will present significant limitations in future in providing broadband services such as IPTV, video on demand, video games, videoconferencing, internet, distance learning, etc. One solution would be implementation of FTTH network in Kosovo as the access network. This would eliminate restrictions on the copper wire access network and should provide a safety network for a long period of time.

There are several architectures and technologies of FTTH network, but as most appropriate and most favorable architecture and technology for implementation in Kosovo is proposed PON architecture, namely its GPON standard.

This paper will analyze the advantages and disadvantages of the proposed architecture of PON, respectively GPON standard, and will be given the reasonableness of their implementation. It will analyze the concrete possibilities of practical implementation of a FTTH network in terms of Kosovo, depending on the location and the opportunities that exist for this realization. It will also analyze the implementation cost of a FTTH network, where as a model network for such analysis is used the connection of the 10 houses. At the end, will be analyzed and discussed the results of measurements performed for two wavelengths: λ = 1310 nm and λ = 1550 nm.

***Keywords* —** FTTH, PON, GPON, Access network, Architecture, Fiber optic, Kosovo.

I. INTRODUCTION

The fact that the ambitions and demands for more advanced services such as IPTV, videogames, videoconferencing, internet, distance learning, etc., are constantly growing, has made that service providers are often in uncomfortable position concerning the fulfillment of customers requirements. On the other hand, it is known that the copper media have limited capacity and speed [1]. The data transmission capability of Digital Subscriber Line (DSL) systems is to several Mbps.

These limitations of copper wire network hustled the service providers to move towards other technologies. One of the most appropriate technologies is undoubtedly fiber optic technology. Fiber optic technology, compared with copper wires technology is faster and has greater bandwidth, because it uses light impulses instead of electrical signals for data transmission. Also, it is immune to electromagnetic interferences and less susceptible to signal (impulse) degradations.

In order to provide the best possible services to users, service providers made even bolder steps, sending optical fiber to the customer termination point (CTP), a technology known as fiber-to-the- home (FTTH).

Given the rapid growth trend of optical technology throughout the globe, Kosovo too has made positive steps in this direction, extending hundreds of kilometers optical cables across its territory. Most of fiber optic network was carried out by company "Post-Telecommunications of Kosovo" (PTK).

In this paper a special importance will be paid to the architecture of optical fibers in Kosovo, where we will dwell on a detailed analysis regarding the proposal most advantageous architecture for FTTH implementation in Kosovo. In this case the advantages and disadvantages of the proposed architecture will be, also, identified in order to justify the implementation of the proposed architecture. It is also analyzed the implementation cost of a FTTH network, where as a model network for such analysis the connection of the 10 houses is used. At the end a possible model of implementation of a FTTH network in Kosovo is given and the appropriate measurement and analysis done.

II. EXISTING ARCHITECTURE

Currently the entire transmitter network in Kosovo is based on fiber optic and microwave technology, while the access network is based on copper cables.

In developing their strategies, companies operating in Kosovo are examining the possibilities of implementing access technologies based on fiber optic (Fiber to the x, FTTx) and wireless network to increase speed of access network.

Relying on needs for greater and greater bandwidth, which is an essential prerequisite for the realization of the ever increasing demands by customers for greater access speed to Internet, video services, IPTV, VoIP, and multimedia services, necessarily has shown the need that companies to be oriented towards the beginning of greater use of optical fiber (FTTX) in the access network.

In 2002 in Kosovo there were only a few kilometers of optical cables laid [2], while today there are over 1000 km. The optical ring (ring network with optical cable), implemented by the PTK, links major cities of Kosovo and some villages, making the first steps towards the implementation of FTTH technology (Fig. 1).

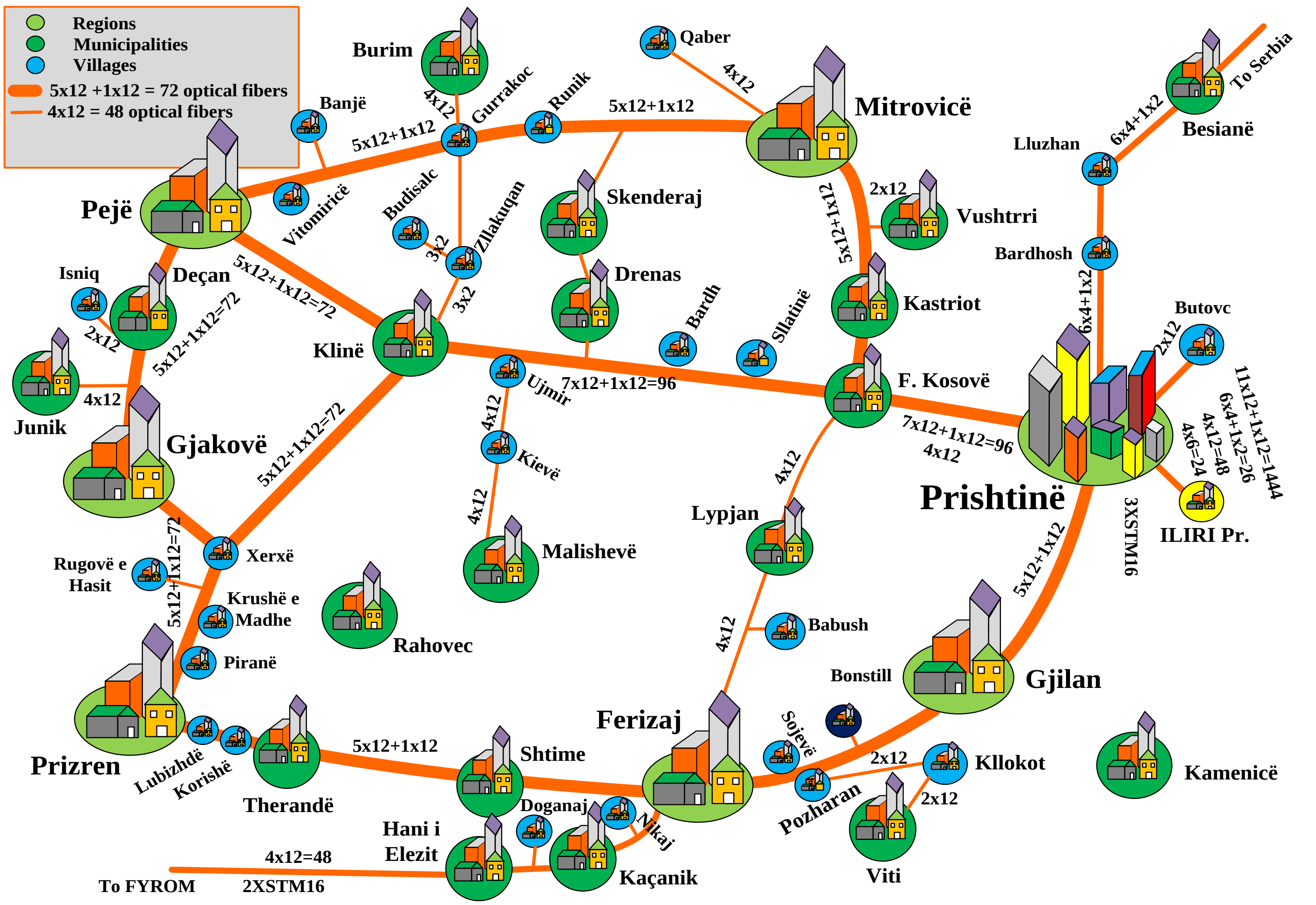

Fig. 1. Current optical network in Kosovo implemented by PTK. Source: Post and Telecommunications of Kosovo (PTK). (Synchronous Transport Module – 3x STM 16 = 3x 16 x 155.52 Mbps = 3x(~2.5 Gbps))

From Fig 1 it is shown that Kosovo has achieved to have a pretty good stretch of the fiber optic network, but to achieve long term goals and to be in step with technology, there is still much work to be done. It may be asked: why to implement FTTH in Kosovo? It is true that current demands by consumers in Kosovo can be realized through the copper access networks. But to answer this question let us anticipate the evolution of services and the need for higher speed.

Voice: It is known that the speed from 64 kbps is standard and typical for the transmission of speech I TDM (Time Division Multiplexing) technology. With the modernization of telecommunications infrastructure, technology already implemented and functional, PTK and other companies are oriented towards the application of VoIP (Voice over Internet Protocol) services, which requires slightly greater speed, about 100 kbps. This migration opens the way for delivery of multimedia services, thus the need to increase this speed. For example, the user of the Skype VoIP services, has started the attachment of the photos and the use of the PC web cameras, resulting in 5-10 times speed increase.

Video: Today video signal in Kosovo is delivered through public microwave transmitter, satellite or cable. Channels are transmitted in different frequency bands.

The need for greater bandwidth (speed) is presented with [3]:

1) The jumping from frequency video transmission to IPTV.
2) The actualization of the need for reception of high quality (definition) video signal – HDTV.
3) The providing of video on demand (VoD) services, etc.

III. Capacity Needs Assessment

The figures and tables you insert in your document are only to help you gauge the size of your paper, for the convenience of the referees, and to make it easy for you to distribute preprints Capacity needs assessment for today, within 2-3 years and for the next 5 years is presented in tables 1, 2 and 3 [3].

Table 1. The need for capacity today

Item	Minimal Needs	Maximal needs
Voice	64 kbps	100 kbps
Data	1 Mbps	2 Mbps
Video (2 SDTV)	4 Mbps	6 Mbps
HDTV (up to 40”)	6 Mbps	9 Mbps
Total	**11 Mbps**	**17 Mbps**

Table 2. The need for capacity within 2-3 years

Voice/ Multimedia	300 kbps	600 kbps
Data	2 Mbps	4 Mbps
Video (2 SDTV)	4 Mbps	6 Mbps
HDTV (27”)	3 Mbps	5 Mbps
HDTV (50”)	10 Mbps	15 Mbps
Total	**19 Mbps**	**30 Mbps**

Table 3. The need for capacity for 5 next years

Voice/ Multimedia	1 Mbps	2 Mbps
Data	5 Mbps	10 Mbps
HDTV x 2 (35”)	6 Mbps	8 Mbps
60 frames per seconds, SHDTV (over 50”)	20 Mbps	25 Mbps
HDTV (PIP)	6-8 Mbps	8 Mbps
Total	**38 Mbps**	**53 Mbps**

Summary of capacity needs for today and the next 5 years is presented also in graphical form in Fig. 2 and Fig. 3.

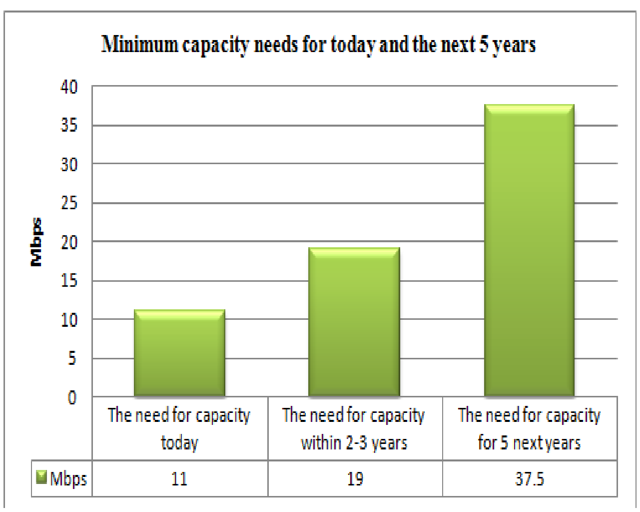

Fig. 2. Minimum capacity needs for today and the next 5 years.

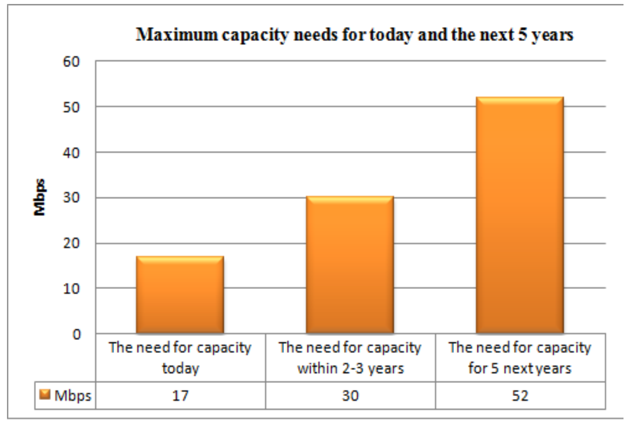

Fig. 3. Maximum capacity needs for today and the next 5 years.

One could note from these results that the fulfillment of these demands for higher speed in the longer term is impossible for access networks based on copper cables.

The DSL access networks based on copper cables have limitations in terms of capacity and distance of the customer and based on the existing situation (the length of the network) we can count on the speed that runs approximately 10 Mbps [4]. While new versions of DSL technology, ADSL2+ and VDSL2, provide 15-20 Mbps speed and 40-50 Mbps respectively, which as we can seen they can not offer a solution for the next (future) years. Therefore as the only solution which would satisfy the ambitions of the users in the coming years will be implementation of the FTTH technology/architecture.

IV. The FTTH Architecture Proposed for Implementation in Kosovo

In Kosovo, although there are some companies that offer mobile telephony and internet, with the exception of mobile telephony, still many rural areas are left without proper communication infrastructure. Companies are constantly working on providing the best possible services, not excluding FTTH technology to all residents of Kosovo who want to be their clients. This can best be seen in the Fig. 1, where a number of villages have already been connected to the telecommunications network by fiber optic cable. This shows the intentions of companies in Kosovo towards FTTH. On the other hand, the territory of Kosovo is organized so that the majority of rural areas are rather grouped, creating very favorable conditions for service providers to implement FTTH at a cost not too high.

Given the expansion of settlements in Kosovo, the most suitable architecture for implementation of FTTH would be PON. Why PON? PON has a lower cost implementation [5]. Why lower cost? In the case of point-to-point (P2P) architecture, individual fibers run from the central office to each home or to end-user building [6]. This architecture requires separate fiber optic cable for each end-user. This makes the first installation to have a very high cost. On the other hand, the point-to-multipoint (P2MP) architecture uses a single fiber for multiple premises [7]. But this architecture needs the active splitter which requires a continuous supply of energy, which increases the cost of maintenance. Unlike P2P and P2MP network, PON network has a simple structure: the same transmission medium is used by more clients, and no need for active devices. All that is required for PON network is the passive optical splitter. Passive optical splitter requires no power supply, having a direct impact on reducing costs for maintenance and network configuration. Given these, we can conclude that PON architectures would be among the most favorable for implementation in Kosovo.

The main generations of passive optical network (PON) technology are: ATM passive optical networking (APON), broadband PON (BPON), Ethernet PON (EPON) and Gigabit PON (GPON). The main differences between these technologies (standards) are: operating speed and type of processing of packets.

Which one of these technologies to use for implementation of FTTH in Kosovo? As the most appropriate technology will be GPON. Why GPON? BPON has limited capacity to 622 Mb/s [2], [8], which when divided into 32 end-users will result in insufficient capacity within 2-3 years. While EPON offers a speed of 1 Gb/s [5] and compared to BPON, EPON has a lower cost for implementation. GPON technology is designed for access networks, taking into account the specifics of telecommunications service operators. For GPON the flexible standards [9] are defined that enable interoperability with existing networks, whether TDM, ATM or IP/Ethernet [8]. In addition, GPON has a significant advantage in terms of transmission speed compared to other technologies.

From this, one can see that even though the EPON and the GPON have gigabits speed, the GPON has considerably higher speed than the EPON [10], and a number of advantages compared to other technologies. So, companies in Kosovo, when deciding on an investment such as FTTH, must choose the technology that will ensure **sustainability** of the investment made at least 10 to 20 years in the future. Therefore, GPON technology, relying on its advantages over other technologies, would be most appropriate technology for use in Kosovo for FTTH.

V. Advantages and Disadvantages of Implementation of FTTH Technology in Kosovo

Advantages of FTTH network implementation in Kosovo, can largely be divided into two groups: the advantages associated with the service provider and the advantages associated with the service user.

Advantages of FTTH technology for the providers of service are:

1) Very large transmission medium and speed.
2) Network immunity against electromagnetic interfering.
3) Easy and fast installation.
4) Low-cost maintenance.
5) Low cost for connecting additional users.
6) Simple configuration and administration, using dedicated management network systems (the testing of network and equipments, the control/command of equipment, the network interference, etc., which can be carried out remotely without having to go to the customer or equipment/device).
7) Low losses, less than 0.5 dB/km. This has impact in increasing the quality of transmission and reducing the number of devices for amplification or regeneration of signals in FTTH networks, compared to traditional copper networks or microwave networks.
8) Increased reliability of broadband transmissions in comparison to other networks, either today or in the future.

Advantages of FTTH for the users of services are:

1) High bandwidth
2) Shortening the time of searching and browsing on the Internet.
3) Increased security at home or in any other building, keeping it under surveillance through video monitoring.
4) Represents a wide range of opportunities to learn or to search the site regardless of where you are, using electronic learning.
5) Ensure that access to work areas (meetings, workshops) without being present, through the videoconferences.
6) Provides interactive entertainment, e.g. various videogames, internet protocol television (IPTV).

Besides the advantages, implementation of FTTH has some drawbacks, such as:

1) Cost of implementation of FTTH is still too high
2) There is no real need for FTTH technology currently in Kosovo.
3) The current economic situation of Kosovo and the large number of unemployed may make such an investment by the companies not be able to justify.

As shown, the disadvantages when compared with the advantages are very small. Thus, companies that provide communication services in Kosovo, in order to maintain primacy in the communications market in Kosovo, and to afford the competition that exists in Kosovo should think in the future for such a strategy to implement FTTH networks.

VI. Implementation of FTTH Network in Kosovo

In Fig. 4 is shown the implementation of a FTTH connection for 10 houses. The FTTH distribution is presented starting from patch panel, where passive distributors are placed. Patch panel can be placed in the basement or in the annex of a house, or in any special place somewhere in the neighborhood. For this distribution it is planned to use a 1x4 splitter and 3 passive splitters 1x32. From the patch panel an optical cable with 8 fibers will be sent to each house. Fibers will be sent to the cabinet which is placed somewhere near the house. From the cabinet, 2 of 8 fibers will be sent to optical line unit (OLU), which is placed in the customer termination point (CTP). Other 6 fibers sent to the cabinet will serve as spare fibers which can be used by different companies operating in Kosovo to provide various customer services. In this case the whole network is passive, with the exception of the OLU device, which requires electricity. This is the main reason why the PON technology is proposed for implementation of FTTH.

Since many villages in Kosovo are grouped, the realization of such an optical network will be quite convenient and cost not too high. Such a network implementation is especially suited in the case of building new neighborhoods, whether in rural or in urban areas, since the extension of optical fiber can be accomplished simultaneously with the construction of associated infrastructure to neighborhood, as sewer, water, etc. This would reduce the cost in terms of realizing such an optical network access.

For such a case of FTTH network carried out specific measurements using JDSU MTS-**6000** device [11].

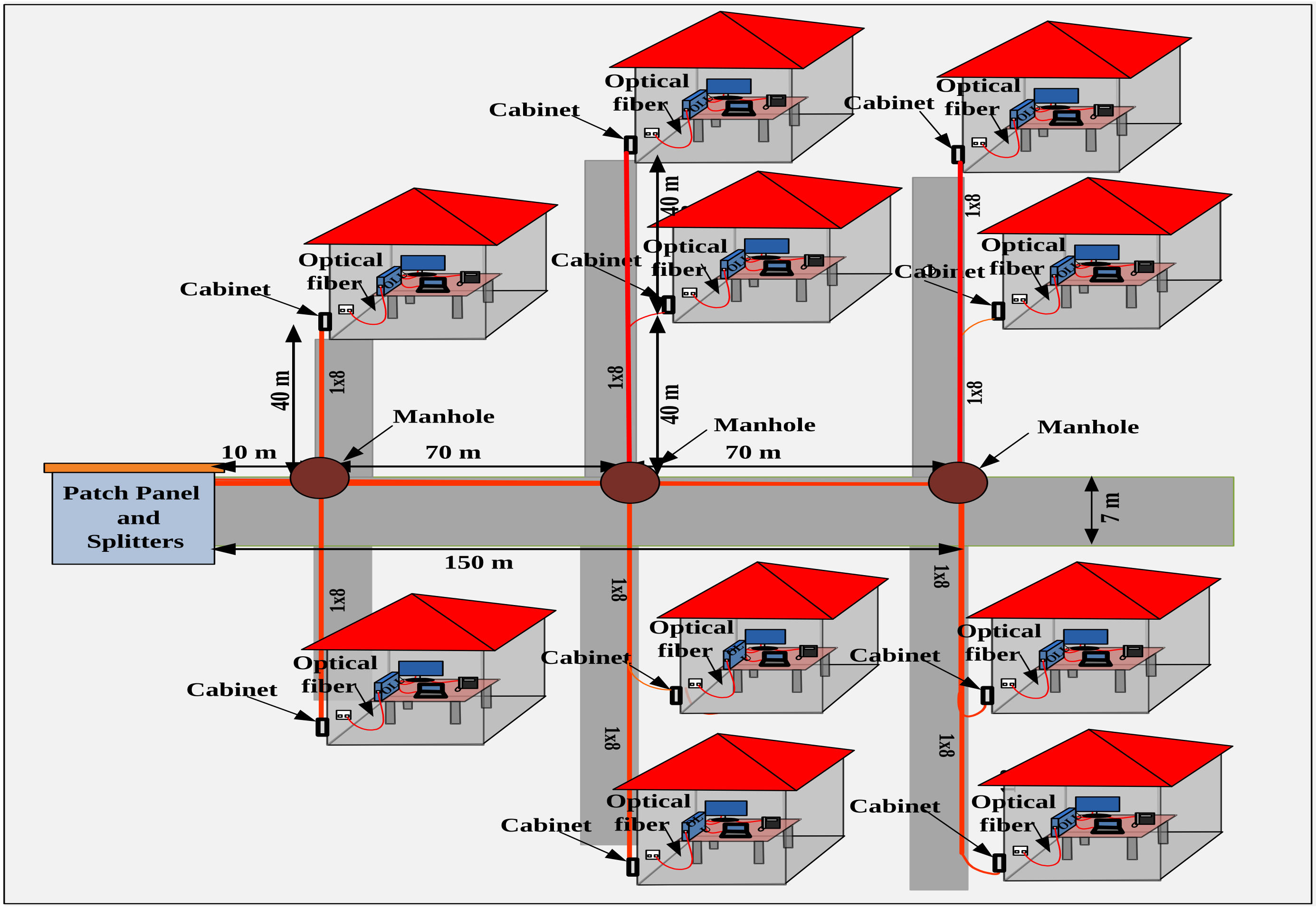

Fig. 4. Implementation of a FTTH connection for 10 houses.

VII. Financial Cost of Implementation of a FTTH Network for a Model Neighborhood of 10 Houses in Kosovo

In this section will be discussed financial aspects of the implementation of a FTTH network for a model neighborhood of 10 houses (Fig. 4). Since the financial cost to be made clear is given a summary table of prices for the necessary equipment that a network done according to such a model of the FTTH network can be accomplished. This summary is presented in Table 4 and is the result of market research equipment in Kosovo and in the Internet.

Table 4. Financial cost of implementation of a FTTH network

Nr.	Item	Unit	Quantity	Min. price (€)	Max. price (€)	Min. total amount (€)	Max. total amount (€)
1.	OLU/ONT	Piece	10	100	200	1000	2000
2.	Optical splitter 1x4	Piece	1	50	150	50	150
3.	Optical splitter 1x32	Piece	3	100	200	300	600
4.	Optical cable SM – 1x8 fibers	m	1435	0.50	0.65	717.5	932.75
5.	Extension cable 0.5-1 m (in the	Piece	80	5	5.5	400	440

	distribution box)						
6.	Extension cable 3 to 5 meters (on the client side)	Piece	20	6.5	8	130	160
7.	Connector FC/SC	Piece	160	3	4.5	480	720
8.	External metal cupboard	Piece	1	550	850	550	850
9.	Box with 8 modules in the wall of the house (outside or inside)	Piece	10	65	85	650	850
10.	Distribution box inside cabinet, with distribution/patch panels and with 96 modules	Piece	1	380	480	380	480
11.	Metal tape marked "Caution! Optical cable"	m	550	0.20	0.25	110	137.5
12.	PVC protection with dimensions 100 cm x 20 cm x 0.2 cm	m	550	0.4	0.45	220	247.5
13.	Excavation of the canal 40 cm wide and 100 cm deep	m	550	1.5	2	825	1100
14.	Fine sand (20 cm)	m^3	44	13	15	572	660
15.	Gravel (20 cm)	m^3	44	11	12	484	528
16.	Concrete tube manhole - with dimensions Ø100 cm, h = 60 cm	Piece	3	300	600	900	1800
17.	Polyethylene (PE) tube Φ125 mm	m	150	2	2.5	300	375
18.	Polyethylene (PE) tube Φ50 mm	m	400	1.5	1.8	600	720
19.	Tube coupling Φ125 mm	Piece	4	0.8	1	3.2	4
20.	Tube coupling Φ50 mm	Piece	6	0.7	1	4.2	6
21.	Cover of the tube with the cable inside the tube	Piece	6	1	1.5	6	9
22.	The holder of additional optical cable	Piece	1	8	10	8	10
Total (Euro)						**8689.9**	**12779.75**

One such cost is for the case when the realized network is passive and when we are dealing with new buildings, respectively, as for the case proposed in fig. 4.

If in the implementation of such a case the active devices are included, then there must also to be included the cost of energy supply (including monthly payment of energy), and the cost of maintenance of active equipments/devices.

If we want such a network to accomplish for a neighborhood in which the accompanying infrastructure such as drainage, street paving, sidewalks, etc. is completed, then to the cost of implementation must be added the cost of repairing sidewalks, asphalt, various drilling etc. This will affect the cost of implementation to increase for 60% to 80% of the total cost, which is unaffordable for companies operating in Kosovo.

A cost reduction would be in this case if some of the works, such as: opening the channels, purchase of pipes (tubes), and some additional work will performed in collaboration with other companies, such as the Kosovo Energy Corporation (KEK) and Water Companies [3].

VIII. Results and discussions

The losses due to reflectance (in dB) and the losses along the optical fiber (in dB/km) are measured for two wavelengths: λ = 1310 nm and λ = 1550 nm and presented in graphical form, using *Fiber Trace Viewer* software.

Measurements were conducted and analyzed for two cases.

The first case: Along optical fiber appear the different reflectances and signal losses during light propagation, as a result of fiber bending caused during its laying.

Measurements are performed for λ = 1310 nm and λ = 1550 nm. In Fig. 5 is presented the case for λ = 1310 nm, while in Fig. 6 is presented the case for λ = 1550 nm.

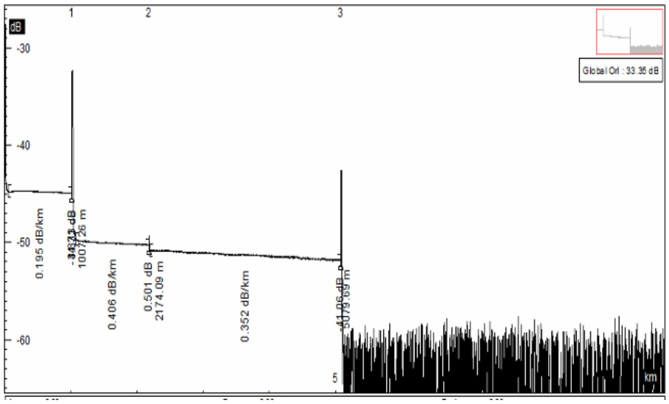

Fig. 5. Graphical representation of measurements for the first case for λ = 1310 nm.

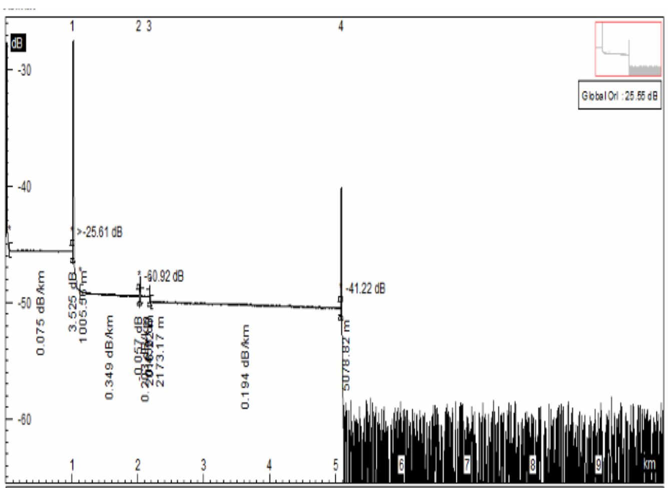

Fig. 6. Graphical representation of measurements for the first case for λ = 1550 nm.

From this can be seen that for the distance of 1 km (point 1 in Fig. 5 and 6) at λ = 1310 nm, the loss is 0.195 dB/km, while for the same distance at λ = 1550 nm the loss is 0.075 dB/km. From 1007 m to 2173.17 m, the loss for λ = 1310 nm is 0.406 dB/km, while for λ = 1550 nm the loss is 0.349 dB/km. In the distance 2173.17 m, as a result of the fiber bending, we have 0.501 dB loss for λ = 1310 nm, and 0.458 dB loss for λ = 1550 nm. At λ = 1550 nm, in the distance 2016.22 m, a reflectance of -0.92 dB appear. This reflectance does not appear at λ = 1310 nm. At the distance between 2016 m and 2173 m the loss is 0.203 dB/km, for λ = 1550 nm. At distance from 2173 m to 5079 m the loss is 0.352 dB/km for λ = 1310 nm, and 0.194 dB/km for λ = 1550 nm. The total loss is 7.065 dB for λ = 1310 nm, and 4.95 dB for λ = 1550 nm. This shows that when transmission is performed λ = 1550 nm, the total loss is smaller for more than 2 dB.

The second case: The fiber is analyzed within a shorter distance than in the first case, but with a much better laying than in the first case. In Fig. 7 is shown the case where transmission is realized at λ = 1310 nm, while in Fig. 8 is shown the case where transmission is realized at λ = 1550 nm.

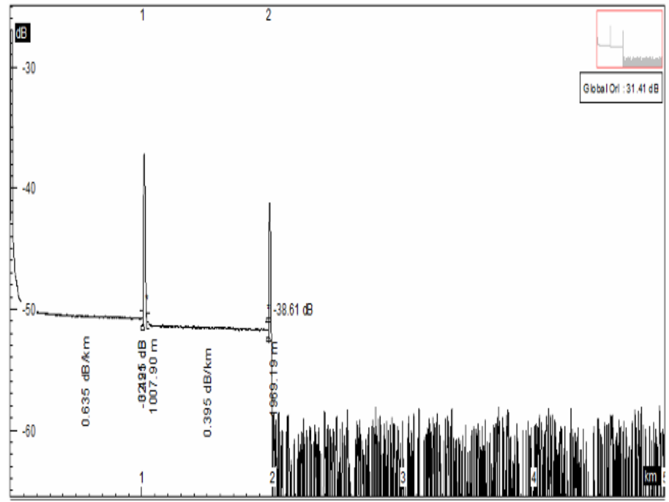

Fig. 7. Graphical representation of measurements for the second case for λ = 1310 nm.

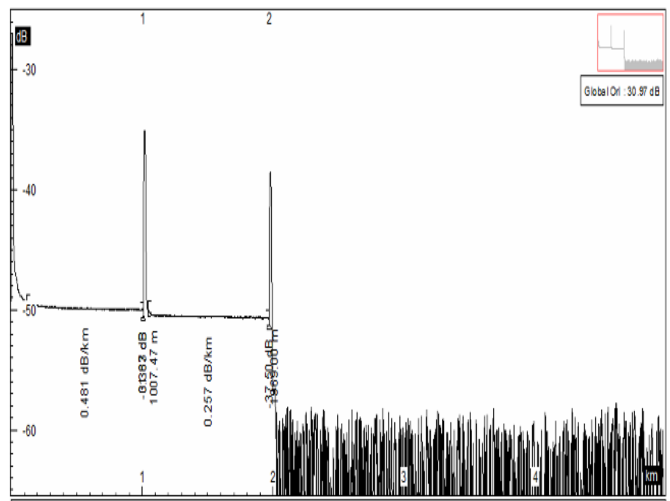

Fig. 8. Graphical representation of measurements for the second case for λ = 1550 nm.

In the second case, compared with the first case, the total distance is 1969 m, a distance of approximately 3 km shorter. From this can be seen that for distance 0 m to 1007 m, the loss for λ = 1310 nm is 0.635 dB/km, while the loss for λ = 1550 nm is 0.481 dB/km. From distance 1007 m to 1969 m, the loss for λ = 1310 nm is 0.395 dB/km, while for λ = 1550 nm, the loss is 0.257 dB/km. The total loss is 1.515 dB for λ = 1310 nm, and 1.099 nm for λ = 1550 nm. In this case even the distance of fiber is shorter, the difference in loss, depending at which wavelength the transmission is realized, is significant.

In this case (second case), total length of optical fiber (including optical launch cable) is 1969 m. Total losses for 1310 nm wave length are –1.515 dB, while for 1550 nm wave length are –1.099 dB. If the output power should be 1.5 mW, what should be the input power?

For the case when the wavelength is 1310 nm, the required input power is:

$$P_i = \frac{P_o}{10^{\frac{L_{dB}}{10}}} = \frac{1.5\ \mathrm{mW}}{10^{\frac{-1.515}{10}}} = 1.5\ \mathrm{mW} \times 1.42 = 2.13\ \mathrm{mW} \quad (1)$$

If calculations are made for 1550 nm wave length, then we have:

$$P_i = \frac{P_o}{10^{\frac{L_{dB}}{10}}} = \frac{1.5\ \mathrm{mW}}{10^{\frac{-1.099}{10}}} = 1.5\ \mathrm{mW} \times 1.29 = 1.93\ \mathrm{mW} \quad (2)$$

From this it can be noted that although the length of the tested optical fiber is little, the difference in required input power is considerably between these two cases. For the case when the transmission is realized in the 1550 nm wavelength, the required input power to gain the necessary power of 1.5 mW in the receiver is for 0.20 mW less than if the transmission is realized in the wavelength 1310 nm.

IX. Conclusion

In this paper the current architecture of optical fiber in Kosovo has been analyzed. The current and in the future expected requirements for speed and the possibilities of meeting these requirements through the implementation of FTTH are discussed. In this context, the best possible FTTH architecture for implementation have been proposed. Based on the cost of implementation, simplicity of implementation and capacity, we concluded that the most appropriate FTTH architecture is GPON.

This conclusion is based on the following parameters: territorial organization of Kosovo, the need for capacity in the long term period, the advantages of this technology (capacity, flexibility, etc.), and cost of implementation.

In this case, the concrete possibilities for the practical realization of a FTTH network in terms of Kosovo are analyzed, depending on the location and the opportunities that exist for this realization. The implementation cost of a FTTH network is also analyzed, where as a model network for such analysis the connection of 10 houses is used. From the analysis made we came at the conclusion that realization of a FTTH network in Kosovo is more suitable for those areas or neighborhoods in which the associated infrastructure is not yet regulated, and those neighborhoods that are being built as a new neighborhood (greenfield), or anticipated to be constructed in the future.

This finding is based on the cheapest cost to implement a FTTH network, because in this case could be used extending of optical cables at the same time when the accompanying infrastructure of the district/neighborhood such as sewer, water, etc. is realized. So the cost of a FTTH network will be much lower and affordable by companies involved in providing communications services in Kosovo. Also, from measurements made, we came at the conclusion that if the transmission is realized at λ = 1310 nm losses will be larger for the same distance than when the transmission is realized at λ = 1550 nm.

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