Selection of Telecommunication Access Networks

Predrag Katanić

University of East Sarajevo predrag.katanic@gmail.com

Contribution to the state of the art

DOI: **10.7251/JIT1401005K** UDC: **004.738.5.057.4**

Abstract: The development of Internet technology and computer networks leads to the convergence of traditional systems voice, video and data into a unique IP-based TriplePlay system. Differences in implementing TriplePlay service basically come down to the choice of technology of data transmission from the last aggregation point (node) to a subscriber (Last Mile).

Analyzing Internet market, the Organization for Economic Co-operation and Development (OECD) made trend in increasing demand for bandwidth during the period from 2007 to 2017. The analysis is based on SmartHome concept which includes broadband internet as well as multimedia services such as IPTV, cell phones and so on. The results of the analysis to a great extent confirm increasing trend of the consumers' demand for bandwidth defined by Jakob Nielsen. His theory is based on the previous period and predicts that the need for bandwidth will rise by 50% every year. Nielsen's diagram resembles that of Moore which predicts that CPU power will double every 18 months, that is 67% a year.

The constant alterations in market and technology causes dilemma to operators in terms of investment. It is quite difficult to answer the question about the choice of technology of connecting the subscribers from the aspect of both technological and economic justification. Finding the answer to this question is the main goal of this paper.

Keywords: Internet technology, Triple Play, VoIP, IPTV

Introduction

The developments of the broadband access to the internet, as well as internet applications and services in the world are known as key initiators of the total economic growth of society. Broadband internet has become the inevitable factor of insurance for more effective health, education, science, culture, tourism, etc. In the past years the telecommunication market has increased the amount of internet ports and the development of services which rely on broadband access to the internet. However, Bosnia and Herzegovina, when it comes to the number of ports, stays behind in comparison to the countries nearby and the countries of the European Union.

In this paper, evaluated different models of the development of the future regional network for data transferring are also shown. An accent on choosing the future model is put on giving the NGS (Next Generation Services), which are completely based on IP technology. The model must fully support existing services and the existing user equipment, or the service of analog television and analog telephone, as well as to be totally acceptable in the observed environment.

Starting analysis

Within the starting analysis, a research has been done which should describe the model of the future network. The future network should have quality service delivery to the final user, with minimal expenses of implementation and maintenance.

At the beginning of the research, approximate requests have been defined, which the future model should fulfill. Besides the technical and technological aspect, it is necessary to process the economical, social and political aspects, which can affect the model of the future network. In order to better perceive these factors, we made a PEST analysis (Political, Economic, Social and Technological analysis), which was done before the research. The conclusions of the PEST analysis were needed as directions in the research itself. [3]

Economic, social and political analyses have shown advantages and disadvantages of the development of the future regional network. The conclusion of those analyses has shown necessities of the development of the new regional network model for broadband access to the internet and multimedia services based on IP technologies.

Analysis of the technological development has shown the necessity of overcoming the technology gap, which appeared as a consequence of the lack of investments in this region. For that cause, at the beginning of the research technological-technical requests have been defined, which the future network must fulfill. Some of the requests were partially in collision with the others. That collision often comes from the need to retain the existing service models. The solution is a compromise, which occurred as a consequence of the sudden technological leap and the economic incapability of the user to quickly change his equipment. The technological-technical requests are:

1. Future network must ensure access to next generation services (NGS), based on the internet protocol (IP).
2. It is necessary to preserve the existing analog television service on the second and third device at home, as well as the traditional analog telephone, which represents a standard offer from telecom operators.
3. The future network must be adapted to the Digital Agenda for Europe (DAE) requests, that forecast the development of internet technologies until the year of 2020. This comes from the facts that this is an infrastructure project which should have long term service without any big infrastructural changes. [1]
4. Energetic acceptability, the network must acquire the minimum of energy charges.
5. Optimization of maintenance charges, which considers the expenses of taking care of the equipment and the expenses of hiring competent workers.
6. Service control from the beginning to the end, or in other words, from the service source, through the complete network until the final service user.
7. Maximum service flexibility, i.e. complete adjustability to user's requests. A simple service choice which is handled by the user.
8. The Management, Provisioning and Billing system which can support all of the requests of the existing and future users.
9. Besides the PEST analysis it is necessary to research potential market from the aspect of interest with services, which are offered through the future available network. As a research method, a survey and the analysis of received results after data processing was suggested. The survey is done over the complete area of the future access network and has a goal to collect data about future users and their needs for certain types of services. In order for the results of the survey to show a real image of interest and the needs of future users, rules were defined for processing the survey.

Input Parameters for Design

While defining the input parameters for the design of the future telecommunication network it is necessary to maximize performances with minimal costs. The compromise solution should be made and the set technological requirements should not be neglected. On the basis of these hypotheses the following groups of input parameters have been defined:

1. Network capacity,
2. Services,
3. Construction costs,
4. Costs of maintenance,
5. Expansion of infrastructure and service,
6. Possibility of transferring the excess capacity to other operators.

Network capacity. While defining this parameter and due to the lack of national strategy, it has been used the recommendation provided by the European commission for telecommunication development, which has defined the strategy and goals for telecommunication development in the European Union in the project called Digital Agenda for Europe (DAE). Out of the defined goals certain parts are singled out which are related to the recommended capacity of the broadband access. It has been defined that 50 % of household will have had the Internet access faster than 100 Mbit/s by 2020 and 100% of the household will have had the Internet access faster than 30 Mbit/s. According to these goals, two input parameters are defined. [1]

Input parameter 1: *The initial installation has to secure the broadband access to Internet with minimal speed of 100 Mbit/s, regardless of current commercial packages and speed offered.*

Input parameter 2: *The future expansion of the broadband access to Internet with speed greater than 100 Mbit/s has to be replaced with active components, without any interventions done on the passive infrastructure.*

Services. As a basis for defining future services which should be transmitted to the end-user, it is necessary to take into consideration the current condition of the user equipment and trends of the service development. The existing equipment for video service is usually based on analog camera, with constant growth in number of modern digital TV and SMART equipment. Mobile devices also grow in importance as well as services based on IP protocol (Game, VoIP, and IPTV). In order to enable the continuous operations of analog equipment and introduction of SMART devices based on IP protocol two new parameters are defined.

Input parameter 3. *Continuous usage of analog equipment (analog TV and telephone devices) of end-user with the option to replace the outdated equipment with new, without significant change of service.*

Input parameter 4. *The possibility to use the next generation services, which implies open architecture to new technologies and greater flexibility in terms of application of different regulations and business rules.*

Construction costs. The construction costs include potential costs that can appear in the process of construction of infrastructure. They can be easily presented in the following stages:

- Project development costs,
- Obtaining necessary permits,
- Construction of telecommunication infrastructure,
- Laying PVC pipes and fiber optic cabling,
- Passive network components,
- Active network components,
- Customer-premises equipment,
- Testing and commissioning.

The total amount of expenses is not measurable and therefore cannot be used as an input parameter. That is why it is necessary to rationalize and present the total expenses of network construction for one future subscriber. In order to simplify the matter, the future network expansion is not included in the total expenses of an end-user. It is a fact that the future network expansion will make the new subscribers have lower costs of connecting, but due to its unpredictability and great initial uncertainty, this parameter is excluded.

As an indicator of the future network construction costs, one input parameter is defined and presented in a nominal monetary value. This parameter can also be found in the commercial offers when activating the existing cable operators in Bosnia and Herzegovina. The different network models can rationalize certain parts of telecommunication infrastructure and thus cut construction costs. In order to place all future models in the same position concerning infrastructure construction costs, the analysis is based on the universal telecommunication infrastructure. The infrastructure project is done according to standards ISO11801 and EN50173.

Input parameter 5. *Future network infrastructure construction costs.*

Costs of maintenance. When cost of maintenance is concerned, it is necessary to observe and assess regular maintenance practices which include energy costs and hiring of the qualified and skilled workforce. Therefore, while assessing the costs of maintenance, the method of analysis of costs in the previous period on the network segments which have the similar structure as the observed network has been used. This kind of cost is presented in relation to the individual user.

Input parameter 6. *Costs of maintenance of future network infrastructure.*

Expansion of infrastructure. The recommended network has to enable as simple and effective expansion as possible in terms of the number of users without significant alterations in the basic infrastructure. It is also necessary to secure the expansion of capacity on the central location and POP dots arranged in the area. This request is closely related to the potential changes of the future services which would require expansion of aggregate links from the user to the POP dots and further to the central location. This parameter is divided into three other parameters that the future network should enable.

Input parameter 7. *Network should enable simple duplication of capacity of access port in order to increase the number of new users up to 100% without significant alterations in infrastructure.*

Input parameter 8. *It should be possible to segment parts of network into smaller subsystems with the aim of increasing capacities of aggregate and access ports.*

Input parameter 9. *The future network should enable transferring of the excess capacity to other operators on the commercial basis.*

Input parameters 7 and 8 suggest simple procedure of capacity expansion of access network without any new investments in infrastructure. It is assumed that by segmenting network we can divide the growing segment into numerous smaller ones thus increasing the number of users.

Input parameter 9 denotes the legal regulation which defines this area and relates to the operators with significant market shares. Moreover, the tendency of stratification and decomposition of service providing will lead to division on several kinds of providers, such as content providers, Bitstream providers, access providers. This implies that in the near future this network can become part of both access providers and Bitstream providers.

Assessment of Input Parameters Through Fuzzy Model

Analyzing all the defined input parameters for the design of the future access network, we can notice quite different criteria for its assessment. Some input parameters can be numerically assessed, whereas most of them need to be descriptively assessed. Speaking about descriptive marks, it is quite difficult to make a scale for assessment of parameters. The lines between some descriptive marks are very small and often overlap. Descriptive marks are indefinite, which causes a problem when defining the final mark which should indicate the optimal choice.

In such cases one of the possible approaches in assessment is applying fuzzy model of assessment. Contrary to conventional logic, fuzzy logic model does not precisely define an individual element to be part of agglomeration. That element can be copied, but not every element has to be copied [4].

Fuzzy logic is closely related to human perception and denotes rather valuable logic. On the other hand, there is traditional logic with sets of answers (yes/no), (black/white), etc. Fuzzy logic uses precise linguistic variables and counts the correct measures for the features in question according to the approximate observations.

Before applying fuzzy logic model, it is necessary to choose the degree of belonging through a function μ(x), which defines what values (x) meet the condition of belonging to the set A.

$$0 \le \mu(x) \le 1, \quad \forall x \in A \qquad (1)$$

$$\mu_A : X \to [0,1]$$

Fuzzy set is defined as a set of definite pairs.

$$A = \{(x, \mu_A(x)) \mid x \in X, \quad 0 \le \mu_A(x) \le 1\} \qquad (2)$$

The most frequent forms of functions μ(x) are trapezoid and triangle. We have used the triangle in our example, as in Figure 1.

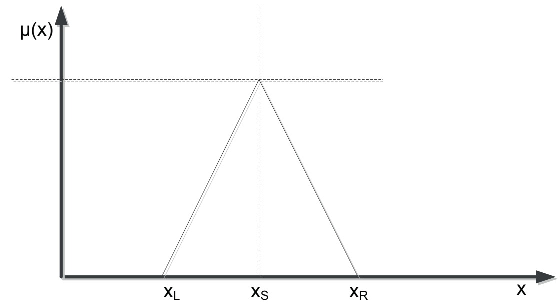

Figure 1. Triangular shape of the fuzzy number

Fuzzy number is calculated according to the following formula:

$$A_f = \frac{x_L + x_R + x_S}{3} \quad (3)$$

x_L, x_R – interval boundary
x_S – maximum of the observed number
A_f – value of fuzzy number.

In order to clarify the measure for fuzzy logic mark, the term fuzzy integral should be defined, which is also known as Sugeno integral. Let X be a finite set and S a subset of X.

$$\mu : S \to [0, \infty] \quad (4)$$

Where μ has the function of positive fuzzy measure.

Let *f* be the finite measurable positive function for the set X,

$$f : X \to [0, \infty] \quad (5)$$

And that the set $F_\alpha = \{x \mid f(x) \geq \alpha\}$ for every positive α which belongs to the series S. The conclusion to this is that it is possible to determine the *fuzzy* measurement F_α for every function *μ(x).*

Sugeno defined the integral of the approximate function *f* for the set X through the following definition:

Let X, S μ be fuzzy measure and let *f* be the positive measurable function defined for the set X. Then we have the following formula:

$$(S)\int f\!l\ \mu(x) = \sup_{\alpha \in [0,\infty]}[\alpha \wedge \mu(A \cap F_\alpha)] \quad (6)$$

Where:

$$F_\alpha = \{x : f(x) \geq \alpha\},\ \alpha \in [0, \infty] \quad (7)$$

The formula 6 denotes Sugeno integral. If we observe the final score of values in the set X, then there is: [5]

$$(S)\int f\!l\ \mu(x) = \max_{i=1..n}\left[\min\{x_{\sigma_i}, \mu(F_{\sigma_i})\}\right] \quad (8)$$

Where σ is a permutation of input measurements for which it is valid $x_{\sigma_1} \leq x_{\sigma_2} \leq \ldots \leq x_{\sigma_n}$.

After analyzing input parameters, four degrees of marks should be defined, that is to say descriptive forms which describe input parameters. The Table 1 shows the defined descriptive forms.

Table 1. Ratings in the literary forms

No	Literary forms	Shortcut
1.	Non-supporting	N
2.	Partially supporting	DP
3.	Supporting	P
4.	Absolutely supporting	PP

Non-supporting (N) – assumes the total mismatch between the model and criteria, th at is the model does not meet the conditions of the criteria.

Partially supporting (DP) – the model could support the set criterion but needs improvement. Quite frequently such improvements are rather expensive and economically unjustified.

Supporting (P) – the model supports the criteria but needs only minimal improvements and costs.

Absolutely supporting (PP) – the model supports the set criteria absolutely without any additional expenses and investments.

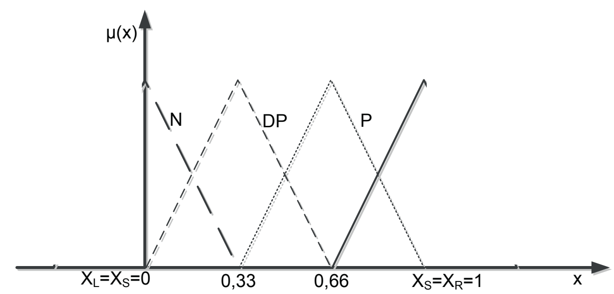

Figure 2. Fuzzy linguistic assessment

Figure 2 shows the triangular position of fuzzy function of the measure $\mu_A(x)$ for every descriptive mark. If we apply these values to the formula 3 we will get the following values for fuzzy numbers.

$$N_f = \frac{0+0+0.3}{3} = 0.1$$
$$Đ_f = \frac{0+0.3+0.6}{3} = 0.3$$
$$P_f = \frac{0.3+0.6+1}{3} = 0.6 \tag{9}$$
$$\mathbf{P}_f = \frac{0.6+1+1}{3} = 0.8$$

The obtained number of descriptive marks quite matches the description of the possible conditions of input parameters. The increase in the number of descriptive marks increases the threshold of sensitivity between input criteria. This might be interesting only if we get two or more different assessments which are very similar or identical. In that case, it would be necessary to increase the number of descriptive marks and repeat the whole process of assessment.

Descriptive marks are presented in the chart in order to be able to clearly determine the correlation between input parameter and its mark for the actual model, and to compare the correlations between the recommended models. Table 2 shows the pattern for evidencing descriptive marks.

TABLE 2. LINGUISTIC EVALUATION OF THE INPUT PARAMETERS (CRITERIA)

Criteria	Model M_1				Model M_2				Model M_3			
	O_1	O_2	O_3	O_4	O_1	O_2	O_3	O_4	O_1	O_2	O_3	O_4
g_1												
g_2												
g_3												
...												
g_n												

O_x – linguistic marks for the observed model and criterion,

g_x – criteria for choosing models of the future network,

M_1, M_2, M_3 – models that are assessed.

For all input parameters which can be numerically presented, we have defined the model of assessment which assumes normalization of values according to the coefficient denoting the lowest value. The formula 10 shows the way we have reached the marks for numerical values.

$$koef = \min\{v_1, v_2, .. v_n\}$$
$$O'_x = \frac{koef}{v_x} \tag{10}$$
$$0 \le O'_x \le 1$$

koef – normalization coefficient,
$v_1, v_2, .. v_n$ – values of the observed model,
O_x – normalized mark.

This way we have got the marks in the same value scope (0….1), and applying the fuzzy model we have got fuzzy marks. These marks could be rearranged with the aim of gaining the final one.

ASSESSMENT OF THE REGIONAL NETWORK MODEL

Applying Sugeno integral we have obtained a separate mark for every input parameter and observed network. The marks are based on different groups of criteria in order to show the correlation between input parameters within the same group. We have got the final mark for every network as arithmetic mean of all other marks for different groups of criteria, which is shown in the following formula. [2]

$$O_{MREŽE} = \frac{1}{n}\sum_{i=1}^{n} O_i(g_i) \tag{11}$$

n – total number of group criteria
$O_i(g_i)$ – mark for the *i* set of criteria.

It should be stressed that there is no difference between the observed groups of criteria when applying arithmetic mean. All marks take equal part in making the final mark of the future network model. If we want to analyze the impact of every group of parameters on the model, then we should adjust the way of assessing. It can be done by making one set of criteria more important than others. This means that the observed group of criteria should be singled out and its marks put on scale with a *k* factor the values of which range from 0 to 1. The other groups of criteria equally distribute the value of the factor *1-k*. Table 3 shows the scaling factor. The chart presents the correlation of the first factor and the same principle is applied for the rest of the factors as for the *k1* factor.

TABLE 3. SCALING FACTOR (K)

k_1	k_2	k_3	k_4	k_5	Σk_i
0	0,25	0,25	0,25	0,25	1
0,2	0,20	0,2	0,2	0,2	1
0,4	0,15	0,15	0,15	0,15	1
0,6	0,1	0,1	0,1	0,1	1
0,8	0,05	0,05	0,05	0,05	1
1	0	0	0	0	1

$$O_{MREŽE} = \sum_{i=1}^{n} O_i(g_i) \times k_i(g_i) \quad (12)$$

n – total number of group criteria
$O_i(g_i)$ – mark for the i set of criteria.
$k_i(g_i)$ – coefficient of scaling for the i set of criteria.

Applying the formula 12 and scaling values k_i in the set interval [0..1], we can make a graph presenting the function of model correlation in relation to the observed scaling factor k_i. Figure 3 shows the characteristic cases of impact of the k_i factor on the value of the mark presented through the functions $f_1(x)$, $f_2(x)$ *and* $f_3(x)$ which represent the observed models M_1, M_2 and M_3.

Let us consider the functions in the cases 1 and 2. The choice of optimal network changes in the points A and B, which are the breakpoints of the observed functions. The values of factors in the points x_A and x_B denote the final value of optimization for model comparison. If the observed values for x_A and x_B points are bigger than 0.35, then we can conclude that after the increase of the impact of 100% in comparison to other factors, the k_i factor offers the function $f_1(x)$ as an optimal solution for the future model M_1.

The cases 3 and 4 show that the observed models are absolutely unrelated and the k_i factor has no impact on the model choice. It is unnecessary to analyze the impact for such cases.

The cases 5 and 6 combine the previous ones. They only show the correlation between two models. If the observed models are correlated, then we can reach the same conclusions as in the cases 1 and 2.

The Table 4 shows the results of the analysis of model assessment in the cases 1 and 2 after defining the optimal distribution of coefficient. The maximal value of the marks for every model defines the optimal model choice. [2]

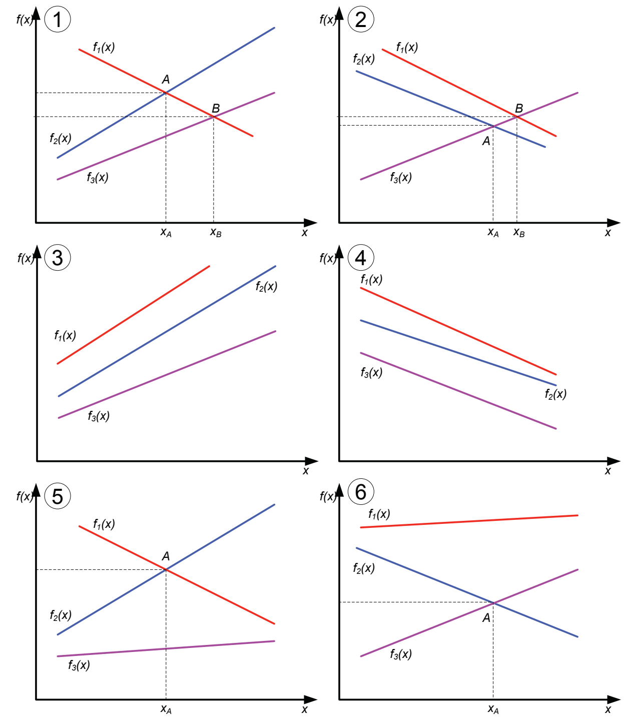

FIGURE 3. CHARACTERISTIC CASES OF IMPACT OF THE K_I FACTOR

TABLE 4. SCALED MARK VALUES WITH OPTIMAL COEFFICIENT DISTRIBUTION

Grupa kriterijuma	Faktor pond.	Model M_1		Model M_2		Model M_3	
		$O_i(g_i)$	$O_i(g_i)xk_i$	$O_i(g_i)$	$O_i(g_i)xk_i$	$O_i(g_i)$	$O_i(g_i)xk_i$
g_1	k_1						
g_2	k_2						
g_3	k_3						
..	..						
g_n	k_n						
Σ	Σk_i		$\Sigma O_i(g_i)k_i$		$\Sigma O_i(g_i)k_i$		$\Sigma O_i(g_i)k_i$

MODEL IMPLEMENTATION: THE CASE STUDY

While searching for the optimal way to evaluate the suggested future access network models, a hybrid model of evaluation was defined. It consists of literal marks on which the *fuzzy* logical model was applied, and numeric marks which we rationalized. To this we were guided by the very fact that the most of input parameters could not be expressed by numerical values and that we did not want the expenses of building a network to be set up as a base. The application of the *fuzzy* model has its own specificities, which depend on many parameters, just like it is shown in the PEST analysis. The PEST analysis has also pointed at complexities of making a decision about the choice of the future model.

As it is defined in the suggested model for evaluation, we did the analysis of the result in two steps, as a prime analysis and as an analysis with scaled influences of group criteria. During the scaling, we wanted to show dependence of the final result compared to the observed group criteria. It is needed to keep in mind the fact that the final result depends a lot from the outside factors. That means that during the defining of input parameters, the PEST analysis has to proceed.

The model was made for a particular area, which has its specificities. In the observed area a survey was done with adjusted content for the chosen area and potential future users. If it is about another area, especially an urban environment, which has an already built infrastructure and available some of the technologies, it is necessary to alternate the model. The outcome of that model can be different than the suggested one, but it can also have a very high level of a result match. That would mean that during the making of the decision about the choice of the access network model, a hybrid form the solution made from combinations of different technologies should be considered.

The suggested model of evaluation and the methodology of access the prescribed criteria can be used as a pattern for evaluation of other network models. The model accents the necessity of the complete overlook of aspects which affect the choice, and not just the short-term economic investment costs effectiveness.

Evaluation of input parameters

Keeping in mind the literal mark defined in Table 1 and the previously mentioned equation, we can calculate the *fuzzy* number for input parameters-criteria. The *fuzzy* number is calculated for the group of input parameters, so we would consider the mutual influence of parameters inside every group.

The criteria for establishing the optimal network choice are divided into four groups, as it is shown in Table 5. We apply the Sugeno integral on the groups with literal marks, while the group with numerically shown marks was defined in the previous chapter.

In Table 5 are shown linguistic marks for the influence of the observed parameter on the model, which came to be as expertise of set out advantages and disadvantages for every suggested model.

For the evaluation of every individual input parameter it is necessary to define the function of the network mark $f_{NETWORK}$. To this function, the values from the group of marks {0.11, 0.33, 0.66, 0.88} are added, which are received based on the group of available literal marks and transformations of those marks in the *fuzzy* value.

Analysis of the evaluation results

For every network model after applying the Sugeno integral, we received an individual mark. Table 6 showcases the marks for all observed criterion groups. The final mark for every network we get as an arithmetic mean of all individual marks from the formula 11. The last column of Table 6 shows the value of the mean. Optimal model choice is represented by the model with the highest average mark.

Table 5. Linguistic marks for input parameters (criteria)

Group marks	Input parameters	HFC				xDSL				FTTH			
		N	DP	P	PP	N	DP	P	PP	N	DP	P	PP
Network capacity	UP1		X				X						X
	UP2		X				X						X
Services	UP3				X	X							X
	UP4		X					X					X
Construction costs	UP5	Numeric marks											
Costs of maintenance	UP6												
Expansion of infrastructure	UP7		X					X				X	
	UP8				X			X				X	
	UP9		X					X					X

Table 6. The values of the Sugeno integral for observed marks

Model network	Network capacity (KM)	Services (SU)	Costs		Expansion of infrastructure (SI)	Final marks
			UP5 (TI)	UP6 (TO)		
HFC	0.33	0.80	1.00	0.90	0.60	0.726
xDSL	0.33	0.60	0.79	0.96	0.66	0.668
FTTH	0.88	0.88	0.72	1.00	0.66	0.828

From this we can make a conclusion that by applying the arithmetic mean of individual marks, the network model candidate based on FTTH technology, represents the optimal choice of the future access network.

It should be accented that while working with the classic arithmetic mean, a difference should not be made between the observed criterion groups. All marks are equally participating in the forming of the final future network model mark.

While using the suggested methodology in the previous chapter and the suggested coefficients for scaling in Table 3, an analysis of individual influence of all input criteria for the optimal access network choice was made. By using the formula 12 in the tabular data record shown in Table 4, we received the following results.

By scaling the influence of investment expenses (TI) in the range from 0 (the investments do not affect the final choice) to 1 (only the investments affect the final choice), we received the results shown in Table 7. The received results show that the breaking point for the coefficient value 0.4 < *k* < 0.5. At this point, the coefficient influence is bigger than 100% compared to other coefficients. By applying the defined methodology, we can consider that after increasing the influence of group criteria for the investment expenses (TI) for 100% compared to other criteria, the choice of optimal future network model stays on the FTTH access network.

Table 7. The influence of investment expenses (TI) on the future model choice

TI	KM	SU	TO	SI	HFC	xDSL	FTTH
0	0,25	0,25	0,25	0,25	0,6575	0,6375	0,855
0,2	0,2	0,2	0,2	0,2	0,726	0,668	0,828
0,4	***0,15***	***0,15***	***0,15***	***0,15***	***0,7945***	***0,6985***	***0,801***
0,6	0,1	0,1	0,1	0,1	0,863	0,729	0,774
0,8	0,05	0,05	0,05	0,05	0,9315	0,7595	0,747
1	0	0	0	0	1	0,79	0,72

By scaling the influence of future services (SU) in the range from 0 (no affect on the final choice) to 1 (it only affects the final choice), we received the results shown in Table 8. The table shows that for any coefficient *k* (∀*k*), the optimal future network choice is the FTTH access network. The received results show the nonexistence of breaking points.

Table 8. The influence of future services (SU) on the future model choice.

SU	KM	TI	TO	SI	HFC	xDSL	FTTH
0	0,25	0,25	0,25	0,25	0,7075	0,685	0,815
0,2	0,2	0,2	0,2	0,2	0,726	0,668	0,828
0,4	0,15	0,15	0,15	0,15	0,7445	0,651	0,841
0,6	0,1	0,1	0,1	0,1	0,763	0,634	0,854
0,8	0,05	0,05	0,05	0,05	0,7815	0,617	0,867
1	0	0	0	0	0,8	0,6	0,88

By scaling the influence of network capacity (KM) in the range from 0 (no affect on the final choice) to 1 (it only affects the final choice), we received the results shown in Table 9. The table shows that only in the case that the observed coefficient is not being considered *k*=0, the future network choice changes for the advantage of the HFC model. For all of the other coefficients *k*, the optimal future network choice is FTTH access network. This scenario is workable in practice only when the network is being built *ad hoc* in order to reach faster acquisition (sale). In all of the other cases, the future access network model choice is the FTTH network.

Table 9. The influence of network capacity (KM) on the future model choice

KM	SU	TI	TO	SI	HFC	xDSL	FTTH
0	0,25	0,25	0,25	0,25	0,825	0,7525	0,815
0,2	0,2	0,2	0,2	0,2	0,726	0,668	0,828
0,4	0,15	0,15	0,15	0,15	0,627	0,5835	0,841
0,6	0,1	0,1	0,1	0,1	0,528	0,499	0,854
0,8	0,05	0,05	0,05	0,05	0,429	0,4145	0,867
1	0	0	0	0	0,33	0,33	0,88

By scaling the influence of maintenance expenses (TO) in the range from 0 (no affect on the final choice) to 1 (it only affects the final choice), we received results shown in Table 10. The table showcases that for any coefficient *k* (∀*k*), the optimal future network choice is the FTTH access network. The received results show the nonexistence of breaking points.

Table 10. The influence of maintenance expenses (TO) on the future model choice

TO	KM	SU	TI	SI	HFC	xDSL	FTTH
0	0,25	0,25	0,25	0,25	0,6825	0,595	0,785
0,2	0,2	0,2	0,2	0,2	0,726	0,668	0,828
0,4	0,15	0,15	0,15	0,15	0,7695	0,741	0,871
0,6	0,1	0,1	0,1	0,1	0,813	0,814	0,914
0,8	0,05	0,05	0,05	0,05	0,8565	0,887	0,957
1	0	0	0	0	0,9	0,96	1

By scaling the influence of infrastructure spreading (SI) in the range from 0 (no affect on the final choice) to 1 (it only affects the final choice), we received results showcased in Table 11. The table shows that for any coefficient *k (∀k)*, the optimal future network choice is the FTTH access network. The received results show the nonexistence of breaking points.

Table 11. The influence of infrastructure spreading (SI) on the future model choice

SI	KM	SU	TI	TO	HFC	xDSL	FTTH
0	0,25	0,25	0,25	0,25	0,7575	0,67	0,87
0,2	0,2	0,2	0,2	0,2	0,726	0,668	0,828
0,4	0,15	0,15	0,15	0,15	0,6945	0,666	0,786
0,6	0,1	0,1	0,1	0,1	0,663	0,664	0,744
0,8	0,05	0,05	0,05	0,05	0,6315	0,662	0,702
1	0	0	0	0	0,6	0,66	0,66

After the executed analysis and showcased results in Tables 7, 8, 9, 10 and 11, and the discussion of the received results, we can make a conclusion that the change of group criteria scaling factors does not influence the choice of the future regional access network model.

From this we can make a conclusion that the suggested FTTH network model is the OPTIMAL SOLUTION for building access networks.

Conclusion

In this paper, a completely new model of input parameters evaluation is represented. It has a goal to choose the future telecommunication network. The results are received by applying the model to an actual situation. They confirmed the initial expectations that were received in the previous analysis.

This paper represents a systemized approach to the future telecommunication access network choice, which has usage in the business environment. The suggested methodology and the defined input parameter evaluation model can represent a base for making the decision about the access network choice in other environments as well, with the input parameters correction.

Authorship statement
Author(s) confirms that the above named article is an original work, did not previously published or is currently under consideration for any other publication.

Conflicts of interest
We declare that we have no conflicts of interest.

Literature

[1] Digital Agenda for Europe , Available: http://ec.europa.eu/digital-agenda/

[2] Katanić, P. (2014) The development and management of regional integrated system for data ransmission. PhD Thesis, Faculty of Electrical Engineering, University of East Sarajevo.

[3] Katanić, P., et al. (2011) PEST analysis of the telecommunications market of Bosnia and Herzegovina. Novi Ekonomist br. 9, str 24-28.

[4] Sugeno, M. and Kang, G. (1988) Structure identification of fuzzy model. Fuzzy Sets and Systems, vol. 28, no. 1, pp. 15–33.

[5] Takagi, T. and Sugeno, M. (1985) Fuzzy identification of systems and its applications to modeling and control. IEEE transactions on systems, man, and cybernetics, vol. 15, no. 1, pp. 116–132.

Submitted: May 7, 2014.
Accepted: May 29, 2014.