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On Ability of Troubleshooting by Observing Some Physical Layer Parameters of xDSL Transceivers

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***Abstract*—This article presents a review of the investigation of the possibility of increasing the efficiency of existing line test solutions for troubleshooting testing for IPTV over xDSL, by the results of experimental research on real system under commercial exploitation. At the beginning of this article the main weaknesses of the existing troubleshooting testing are described. In the continuation of the article the physical layer parameters of xDSL transceiver are listed. This article also provides a few specific examples of xDSL lines with their physical layer parameters of xDSL transceivers followed by analysis how they can be used for the purposes of more efficient measurement of parameters of copper pairs.**

***Keywords*—electrical parameters, IPTV, physical layer parameters, QoS parameters, troubleshooting testing; xDSL.**

I. Introduction

TELECOM operators that deliver IPTV (Internet Protocol TV) service over xDSL lines must meet at least two conditions. The first condition is to implement the FTTC (Fibre to the Cabinet) or FTTB (Fibre to the Building) access networks, thus shortening the length of telecommunication cables made from symmetric copper pairs. Shortening of xDSL lines and the installation of ADSL 2+ (Asymmetric Digital Subscriber Line) or VDSL (Very High-Speed DSL) equipment allows the transmission of higher bit rates of the order of tens, and even hundreds of Mb/s. The second condition is to enable the transmission of the necessary bit rates without the presence of significant levels of uncorrected line errors. Line errors and insufficient bit rates for the required services lead to degradation of IPTV QoS/QoE (Quality of Service/Quality of Experience) parameters.

The two most common types of degradation of IPTV QoS parameters in practice are video pixelization and frame freezes. These two occurrences can occur in any segment of the telecommunication system [1], even on the xDSL line itself. Since the symmetric copper pair is probably the weakest part of the entire telecommunication system, this paper deals with the detection of the cause of the degradation of IPTV QoS parameters due to the occurrences on a copper pair such as different types of faults and interferences. Faults and interferences cause line errors and reduced bit rates.

The problems of degradation of IPTV QoS parameters can be solved in two ways. The first way is by using additional signal and packet processing. Another way is to take physical actions on copper pairs in order to eliminate faults and interferences that degrade IPTV QoS parameters. The first way to solve the degradation of IPTV QoS parameters is much simpler and cheaper because it does not require any physical interaction on xDSL lines. These solutions include DQM (DSL Quality Management) which includes two different techniques: DSM (DSL Spectrum Management) and DLM (DSL Line Management) [2]. In general, DQM is based on the loop shown in Figure 1. DLM techniques include the following basic diagnostic capabilities: SELT (Single-Ended Line Testing), DELT (Dual-Ended Line Testing) and MELT (Metallic-Electrical Line Testing) [3], [4]. DSM systems for dynamic spectrum management have the task to achieve optimal bit rate according to the length of xDSL lines. DSL systems achieve this in one of the following three DSM modes: level 1, level 2, and level 3. With the help of measurements of noise level and crosstalk level for each xDSL line, DSM level 1 selects the best possible settings in terms of line speed, SNR margin and protection against impulse noise for the individual subchannel on line-by-line basis. By choosing xDSL configurations that reduce electromagnetic coupling between pairs in the same cable, DSM level 2 reduces the effects of crosstalk between all lines in the same cable. With the help of the vectoring process, DSM level 3 cancels the crosstalk between lines in the same cable.

Also, there are additional solutions for upgrading xDSL transmission standards [1]. These solutions include: bit-swap, FEC (Forward Error Correction), interleaving, INP (Impulse Noise Protection), packet retransmission on the physical layer, SRA (Seamless Rate Adaption), FEC on the application layer and retransmission of packets on the application layer.

However, all the above-mentioned solutions do not eliminate the causes that degrade IPTV QoS parameters and solutions quite often cannot be sufficiently efficient in practical terms. In all these circumstances, it is necessary to find the real cause of the degradation of IPTV QoS parameters, and then with physical interventions on xDSL lines eliminate phenomena such as faults and interference. In such circumstances it is necessary to perform test procedures called troubleshooting testing.

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Based on the empirical observations of the real system in practice, this paper will discuss solutions that enable the increasement of the efficiency of troubleshooting testing.

II. Properties of Existing Troubleshooting Testing Solutions

Basically, every troubleshooting test procedure is based on the DQM loop mentioned in the previous section. The basic task of troubleshooting testing is to collect, in the shortest possible time, enough valid data on the appropriate parameters that describe the IPTV service, xDSL line and copper pair. After that, it is necessary to make an analysis of these data and perform diagnostics and determine the cause of the degradation of QoS parameters. The ultimate goal is to make the decision which corrective action to take in order to bring the service to the required level of quality.

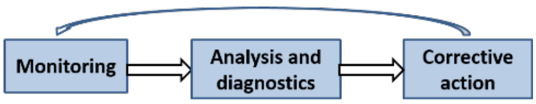

Fig. 1. DQM loop

There are several different parameters describing the IPTV service and xDSL lines through which these services are transmitted. The quality of IPTV services at the network level is described through IPTV QoS parameters (packet loss, throughput, delay, jitter, PCR jitter, continuity error and others). Functioning of xDSL lines is described through physical layer parameters of xDSL transceivers. The quality of the symmetric copper pair as the medium for digital signal transmission is described by electrical parameters (foreign voltage (DC and AC), insulation resistance of copper pair, DC loop resistance, loop length, capacitance, longitudinal balance, near end crosstalk (NEXT), far end crosstalk (FEXT), wideband noise, impulse noise, RF interference, impedance of line, return loss and others).

Troubleshooting testing involves the following [5]: Testing the IPTV QoS parameters allows us to reliably establish which segment of the telecommunication system causes the degradation of these QoS parameters. The next step is testing the physical layer parameters of xDSL transceivers. This step should reliably determine whether the occurrences that degrade the IPTV QoS parameters come from xDSL lines. The next step is testing the electrical parameters of the symmetric copper pair as a signal transmission medium. These tests should determine which occurrences on copper pairs (faults and interferences) cause degradation of IPTV QoS parameters. There are several types of failures and several types of interferences, and their impact on IPTV QoS parameters can be similar, but also quite different. Finally, for the purposes of determining the spatial positions of the points on copper pairs in which faults are present and points that dominantly cause interference, if possible, appropriate measurement procedures should also be carried out. For the purposes of this last step, there are only two possible measurement methods: TDR (Time Domain Reflectometry) and bridged measurement methods. There are no opportunities for any significant improvement of these measurement methods.

The [4] describes an existing test scenario defined by the manufacturer of test equipment (Figure 2). The defined test scenario assumes that data collection for all three types of parameters is done exclusively by manual test devices. This test scenario is efficient when the degradation of IPTV QoS parameters is present at all time or most of the time. However, in practice there are many cases of degradation of IPTV QoS parameters occurring only occasionally, and the causes of such issues are very difficult to detect at all, and thus eliminate. This test scenario requires participation of at least two and very often three employees. In most cases, this test scenario requires the measurement of a large number of electrical parameters, which implies huge time consumption. By applying this test scenario in practice, a team of technical staff can thoroughly examine up to four xDSL lines for eight hours at the best case. Accordingly, that is the maximum number of issues with the degradation of QoS parameters that can be solved by a team on a daily basis. Often, there is no guarantee for this, because not every testing will result in detecting the real cause of the issue. For a significant percentage of issues on xDSL lines, such test scenarios cannot at all enable the correct detection of the cause of the issue. When performing this test scenario, the xDSL lines and services they transmit are out of function.

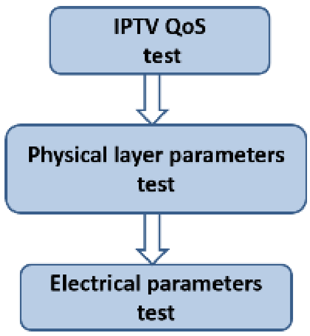

Fig. 2. The flowchart of the existing model's scenario

In addition to the described test scenarios there are other testing options that are available for the testing of all three types of these parameters. For the testing of physical layer parameters of xDSL transceivers and IPTV QoS parameters there have long been very efficient solutions that collect these parameters completely centralized and for very long-time intervals that are even longer than 24 hours [1]. This allows the collection of very reliable data on the values of most of these parameters. Data on both types of parameters can almost always be obtained in a very simple way using appropriate monitoring systems. It is also important to note that the collection of data on the values of both types of parameters is done together with the delivery of services without interruption of services.

When performing the troubleshooting testing measurement of electrical parameters is inevitable in most cases. Measurement of electrical parameters is still predominantly performed using manual measuring instruments. Although the appropriate solutions for partial centralization and automation of these types of measurements have gradually been introduced in the last few years [4], the measurement of electrical parameters still implies the departure of at least two employees on the terrain directly to the location of the users.

Some electrical parameters must be measured on both sides of the line. For one set of measurements of all the listed electrical parameters, in only one pair, it is necessary to spend about 60 minutes, and often more. However, despite the time spent on one pair, and despite the participation of two technical employees, there is no guarantee at all that the measurement of all electrical parameters once will give an answer to the question of what occurrence (faults or interferences) and what type of occurrence causes degradation of IPTV QoS parameters. Also, quite often it will not even be determined whether the faults or disturbances are present at all.

An aggravating circumstance for the reliable measurement of electrical parameters is that some electrical parameters can very often be significantly variable in time. And that means, although the measurement equipment that measures the electrical parameters is very reliable, the measurement results for some electrical can be unreliable. Electric parameters that are variable in time are: wideband noise, impulse noise and foreign voltage.

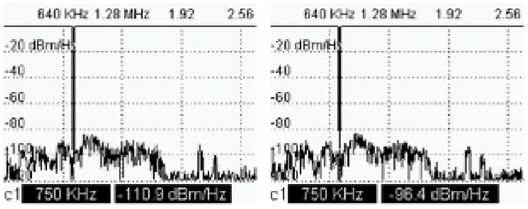

Fig. 3. Example of wideband noise measurements on same line

Wideband noise is noise caused by the activity of adjacent pairs in the same cable. This noise is a phenomenon that will almost always be present on xDSL lines and will mostly affect the appearance of line errors on the lines. For example, if the nearest adjacent ADSL2+ line in the cable is active, the wideband noise level in frequency range from 4 kHz to 3.8 MHz on the observed line without faults can have a level of approximately -34 dBm in the worst case. When the nearest adjacent broadband is inactive, then the broadband noise may be less than about -44 dBm (Figure 3). These are the huge differences in the values of the measured noise on the same line in different circumstances that can happen several times a day. For reliable measurement of wideband noise, this noise should be measured very often during 24 hours period. Of course, such long-term measurements are extremely impractical. The reliability increases with the increase in the number of measurements in different periods of the day. Similarly, for pulse noise and for foreign voltages. This reliability increases by increasing the number of measurements at different times of the day, in accordance with equation:

$$r = f(t, n, a) \tag{1}$$

where are r reliability of measurements of wideband noise, t time period of measurements, n number of different measurements of same parameter and a accuracy of measuring handhold instrument. Similar applies to impulse noise and foreign voltages.

If there are no major faults on the copper pair, and if the line supports sufficient bandwidth, the very presence of wideband or impulse noise is by far the most degrades IPTV QoS parameters (primarily packet loss). In the domain of physical layer parameters of xDSL transceivers, these two noises most often cause a large number of CV (Code Violation) code words with uncorrected errors, and ES (Errored Seconds) and SES (Severely Errored Seconds) in which CV code words occur. Also, these two noises cause the FEC (Forward Error Correction) code words with corrected errors and ECS (Error Correction Seconds) seconds in which these code words occur. Although these corrected line errors do not cause packet loss, their presence is often a significant indication of the existence of interferences.

Table I presents the results of testing the physical layer parameters for five different ADSL2+ lines collected on the real system [6]. These lines represent a significant number of lines in practice. Physical layer parameters of xDSL transceivers listed in the table: FEC, CV, initialization attempts, Unassigned Seconds, SES, ES, LOS (Loss of Signal Seconds) and ECS are presented for a period of full 24 hours.

TABLE I
SOME NUMERICAL RESULTS

Pair	1.	2.	3.	4.	5.
Length	1970	2527	2080	2215	2020
Rate down	4800	4800	7917	4819	7197
Rate up	767	767	1031	775	1031
Max. rate down	19020	8720	17916	15872	18576
Max. rate up	2664	1087	2839	2383	2735
Signal att. down	29.6	31.1	30.6	43.6	23.6
Signal att. up	24.3	25.6	16.4	21.4	19.4
SNR margin down	34.5	7.6	30.6	19.9	20.3
SNR margin up	8	8.2	6.3	7.9	10.6
FEC down	47750	105372	196323	29466	142768
FEC up	3	0	0	0	0
CV down	5043	2162	26355	1722	13399
CV up	436	3	182	195	865
Init. attempts	38	1	1	5	20
UAS down	2949	43	38	185	2812
UAS up	2949	57	48	225	2882
SES down	11	0	9	3	3
SES up	40	0	15	9	47
ES down	244	299	555	86	616
ES up	112	18	55	42	323
LOS down	3	0	1	2	3
LOS up	17	0	0	1	8
ECS down	237	442	412	73	501
ECS up	2	0	0	0	0

Comparing the values of the maximum attainable rate parameters, the signal attenuation and line length with the values that these lines should have according to their line lengths, it can easily be concluded that there is no significant longitudinal galvanic faults or transverse galvanic faults towards the grounded cable sheath on these lines. However, from the value of the CV parameters it can easily be concluded that the number of lost packets on each of the lines is significantly higher than the wanted levels [7]. By further analysis of the values of the ES, SES and ECS parameters, it is clear that these linear errors occur very rarely. Line number 5 is the line with the most errors. If one takes into account the sum of ES + ECS seconds for this line, it is clear from simple math that linear errors in the period of full 24 hours only occur in 1.2% of that time. Therefore, the probability that the use of only manual measuring instruments will detect the presence of degradation of QoS parameters is practically negligible.

Based on the description of wideband noise characteristics and the physical layer parameters for these five lines, it is clear why the test scenario described in Fig. 2 cannot be sufficiently efficient in many circumstances common in practice. It is not difficult to conclude that it is necessary to look for some other testing models. Of course, testing electrical parameters will in most cases continue to be necessary. But it is often possible that we do not need to measure every, but only some electrical parameters. For these purposes, it is necessary to much better use and correctly interpret the physical layer parameters of xDSL transceivers.

III. Physical Layer Parameters of xDSL Transceivers

There is a large number of physical layer parameters of DSL transceivers [8]. For the purposes of this article, only some of them will be used, some of which are already mentioned in this paper and briefly described: maximum achievable rate, actual line data rate, CV (Code Violation) codes, error seconds (ES), severely error seconds (SES), FEC (Forward Error Correction) codes, error correction seconds (ECS), unavailable seconds (UAS), loss of signal seconds (LOS), count of initialization attempts, signal attenuation (Line attenuation), SNR (Signal to Noise Ratio) margin and output power.

As it is already written in this paper, the IPTV service at the network level is described through QoS parameters. Also, the presence of faults and interferences on the physical layer of the copper pair is described through electrical parameters. However, only by knowing the detailed values of the physical layer parameters of xDSL transceivers it can be reliably known whether phenomena that degrade QoS parameters occurred on xDSL lines. Therefore, reliable troubleshooting testing requires the knowledge of detailed values of physical layer parameters for time intervals not shorter than 24 hours.

The physical layer parameters have an impact on levels of IPTV QoS parameters (packet loss, continuity error). Also, electrical parameters of copper pairs affect the values of physical layer parameters for lines with a certain output power and certain actual data. Very small possibility that the incorrect functioning of xDSL transceivers can affect the physical layer parameters is neglected. Also, the existence or absence of faults and interference on copper pairs is determined by the values of electrical parameters. Based on the previously written, logically it can be concluded that the presence or absence of faults and interference on copper pairs is determined by the values of the physical layer parameters of xDSL transceivers.

However, it is not possible to determine an unambiguous link between a fault or an interference with well-defined values of the physical layer parameters, regardless of the previous assertions and some practical observations. Also, there is no unambiguous connection between the exact values of some electrical parameters with exactly defined values of the physical layer parameters. It is only possible to notice and show that certain phenomena on symmetric copper pairs affect to a lesser or greater extent the degradation of physical layer parameters in relation to their values when there is no degradation of IPTV QoS parameters. These facts are detected in practice, and also shown in some papers where it is described that the presence of pre-known failures or interferences affects the appearance of linear errors [9], [10].

However, the following question arises: Based on the knowledge of the detailed values of a number of physical layer parameters of xDSL transceivers, Is it possible to recognize the existence or total absence of some failures or interferences?

IV. New Test Scenario Model

Observations derived from the collection of data on the physical layer parameters of xDSL transceivers and the corresponding values of electrical parameters on the real system in practice for a large number of xDSL lines show that it is quite often possible based on the knowledge of detailed values of the physical layer parameters of xDSL transceivers for long time intervals to ascertain one of the following: 1) To reasonably assume or reliably know the type of occurrence (faults or interference) which causes degradation of the IPTV QoS parameter on the physical layer, and 2) To reasonably assume or reliably know which phenomena do not cause degradation of IPTV QoS parameters.

When it is reliably known or reasonably assumed what phenomena cause the degradation of IPTV QoS parameters, then during the measurement of electrical parameters, as the most important and most time consuming part of troubleshooting testing, some electrical parameters can be devoted more attention than other electrical parameters. And there are situations where some electrical parameters do not need to be measured in any way. Earlier it was mentioned that there are a number of different faults and different interferences. Considering that, a step closer to detecting the causes of degradation of IPTV QoS parameters is the knowledge of what phenomena do not cause degradation of these parameters.

In accordance with the previously described drawbacks of existing test scenarios, a new model of testing is created and presented in Figure 4, [10]. New test scenario model enables that the detection of the causes of degradation of IPTV QoS parameters can be speeded-up in a significant number of cases, based on the knowledge of the detailed values of a large number of physical layer parameters of xDSL transceivers.

As a pre-phase for electric and physical layer parameter testing using handheld instruments, centralized testing of physical layer parameters is introduced through centralized monitoring platforms of DSLAM devices. These monitoring platforms accurately record the values of the physical layer parameters for a period of at least 24 hours, and even more. This is a much longer period of time and therefore much more reliable than handheld instruments that can record these parameters only as long as the instruments are connected to the copper pair. With the help of this test scenario, it becomes possible that, in a significant number of cases, not all, but only some electrical parameters of copper pairs need to be measured.

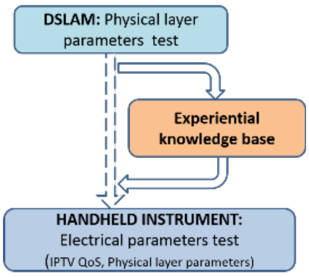

Fig. 4. The flowchart of the new model scenario

By applying such a test scenario technical staff that will carry out tests via handheld test instruments, has a very reliable knowledge of the existence of the phenomena on xDSL lines that degrade IPTV QoS parameters, and quite reliable information about how and how often these phenomena occurs, and in some significant number cases quite justified assumptions on which phenomenon degrades IPTV QoS parameters. In some cases, a significant number of problems will be able to be detected and located, and therefore removed, without the need for measurements of any electrical parameters.

According to the values of some physical layer parameters of xDSL transceivers, a significant number of xDSL lines with degraded IPTV QoS parameters can be classified into one of the following groups [11]:

- Lines without line errors on xDSL, but with problems coming from higher layers of communication,
- Lines closed with xDSL transceivers that function incorrectly,
- Lines with large numbers and frequent errors on the downstream,
- Lines with a large number of downstream errors that are rarely occurring,
- Lines with a significantly higher number of errors on the upstream than on the downstream,
- Lines with a large number of errors on the downstream and/or upstream, whereby most errors can be eliminated by applying correction profiles,
- Lines with a large number of errors on the downstream and/or upstream, whereby largest number of errors cannot be solved, not even by using the additional correction profiles,
- Lines without a significant number of errors, but with significantly lower bit rates on downstream or upstream,
- Lines with significantly more pronounced problems in the afternoon and evening hours.

Of course, xDSL lines can also be classified in several other groups made in terms of the values of some other physical layer parameters.

If in practice there are xDSL lines that differ greatly from one another by some physical layer parameters, then it is logical to assume that these lines will differ greatly from each other according to the values of some electrical parameters. However, in order to know, or justifiably presume, what phenomena (what kind of faults or what kind of interference) on the copper pairs determine the values of the physical layer parameters, it is necessary to have a sufficiently significant statistical sample in practice, and it for each of these groups of lines, measure all electrical parameters. After this, on the basis of such extensive measurements on a huge number of lines, to conclude how, based on detailed knowledge of the physical layer parameters, to sufficiently reliably assume which electrical parameters need to be further measured, and which do not.

In this way we can create a kind of "experiential knowledge base". This "experiential knowledge base" can, in many future cases, based on the similarity of the reports on the physical layer parameters, and before measuring the electrical parameters, enable many future problems in the functioning of IPTV services to be resolved over time more efficiently than now. How? In a way to reduce the number of electrical parameters that need to be measured, or in a number of cases, to omit the need to measure any electrical parameters. Both of them allow time-efficient elimination of the cause of degradation of IPTV QoS parameters.

V. Practical Examples of Application Possibilities

In the continuation of this article, through several examples of detailed reports on the physical layer parameters collected through the DSLAM control platforms, the usability of the application of this test scenario will be demonstrated, on the real system in practice [11], [12]. In practice, we can find a large number of xDSL lines whose parameters are similar to those that will be described. These are ADSL2+ lines, and the data for the largest number of parameters relates to an uninterrupted period of 24 hours.

TABLE II
EXAMPLE OF THE RESULTS, PART ONE

Pair	1.	2.	3.	4.	5.
Length	1402	451	1273	1970	653
Rate down	6170	4819	3470	4800	13352
Rate up	872	771	447	767	773
Max. rate down	16204	22560	4652	19020	23744
Max. rate up	2252	1695	495	2664	1160
Signal att. down	27.6	23.6	39.6	29.6	4.2
Signal att. up	21.3	21.2	52.5	24.3	5.4
SNR margin down	17.5	32.1	6.0	34.5	25.8
SNR margin up	16.1	13.1	6.1	8.0	16.0
FEC down	529150	20218	2	47750	10372
FEC up	1771	107282	8	3	2
CV down	2486	26	8	5049	83
CV up	1797	19647	14	436	52
Init. attempts	0	28	1	38	3
UAS down	0	894	38	2949	113
UAS up	0	954	48	2999	123
SES down	0	6	0	11	0
SES up	0	2186	0	40	0
ES down	277	20	8	244	14
ES up	1371	5564	15	112	15
LOS down	0	3	0	3	0
LOS up	0	0	0	17	0
ECS down	80790	416	0	237	19
ECS up	1120	5971	0	2	2

For Line 1. from Table II, which is 1402 meters long and which at the downstream supports bit rates of 16 Mbps, it can be said that this is a typical example of a line on which there is definitely no longitudinal or transverse galvanic fault to the ground. Accordingly, there is no need for long-term and exhaustive measurements of electrical parameters in order to try to spatially locate something that does not exist. However, given the enormous number of FEC and CV codes, and ES and ECS seconds, it can be concluded that this is the line at which a high level of wideband noise is present. This line is likely to be crossed line with any other close xDSL line, or it may have a poor isolation resistance to a adjacent xDSL line.

Also, on line 2. there is definitely no longitudinal or any transverse galvanic gault to the grounded cable sheath. However, this line has much more line errors on the upstream than on the downstream. Such parameters cannot be caused by another adjacent ADSL2+ line. As the physical layer parameters of this line much differ from the physical layer parameters of line 1., this line must have significantly different values of some electrical parameters than line number 1. Experience shows that lines that are greatly influenced by the environment (e.g. the power cables in the house installation) typically have these parameters of the physical layer. Also, this can be an example of crossed line with another xDSL line whose downstream overlaps with the upstream of this line.

For line 3. it can be immediately noticed that there is too much signal attenuation and much less maximum bit rate at its maximum length. Also, it is noticed that there are no errors on this line. Based on this, it can be concluded that line 3. does not have significant levels of wideband and impulse noise. These results are shown only by lines that have very pronounced longitudinal galvanic faults. At such values, the physical layer parameters should immediately be accessed through measurements via TDR instruments and without measuring any electrical parameters.

Based on the values of physical layer parameters for line number 4. in Table II, it is more than clear that the physical medium in the access network causes issue in the functioning of this xDSL line. There are many uncorrected errors on the line, and a large number of forced count of initialization attempts. There is often a loss of signal. However, if we look at the sum of the counters for ECS, ES and SES, the sum of these counters is 492 s, which is only 0.6% of all seconds in the 24-hour period. Also, only 2.949 UAS was detected, i.e. 3.4% of the full 24 h. If only the electrical parameters were measured on this line using handheld measuring instruments, most likely no line faults would be detected and it would be wrong to conclude that there are no issues on the line. But, taking into account the detailed values of the physical layer parameters, it is very clear that there are very intense line errors that are very short in time.

This means that electrical measurements on such lines should be carried out several times until the real cause of the problem is detected. On the example of such xDSL lines, this new test scenario may not enable time-efficient electrical measurements to be made, but it can be enough to indicate which phenomena need to be pay more attention to. Taking into account the value of the SES and LOS counters, it can be reasonably assumed that this is an example of a line on which impulse noise is occasionally occurring.

Line number 5. in Table II seems to have similar results as line number 4. It is possible to notice the appearance of a significant number of FEC code words, and a significantly lower number of CV code words in a very short time. It is also noted that the line had several losses of xDSL signal synchronization. However, it is noticed that the counters for SES and LOS do not show any value. Therefore, it is unlikely that the cause of the problem here is the occasional appearance of impulse noise. The impulse noise level that is strong enough to expel the xDSL line from synchronization would have to produce a significant number of CV codes, but also cause a significant number of SES seconds. This is a typical example of a line where there is a relatively poor physical contact on one of the conductors in pairs in places where some phenomena such as temperature or vibration can lead to the occasional physical separation of any weak contact. The consequence of this is the sudden loss of the synchronism of the DSL transceiver.

TABLE III
EXAMPLE OF THE RESULTS, PART TWO

Pair	6.	7.		8.	
Length	1328	2249		1912	
Time period				10h	24h
Rate down	6063	7056	6200	4800	1800
Rate up	903	1019	863	767	767
Max. rate down	16420	15232	18.7	7200	
Max. rate up	1208	2164	12.3	991	
Signal att. down	21.3	49.6	43.1	57.6	
Signal att. up	10.8	25.8	21.1	23.5	
SNR margin down	10.0	15.5	15.0	7.7	17.5
SNR margin up	11.8	8.5	10.9	8.0	7.5
FEC down	0	788482	4347338	0	0
FEC up	0	0	1	0	0
CV down	6	507318	48	907	16203
CV up	1	1	1	0	0
Init. attempts	13	0	0	0	4
UAS down	192	0	0	0	73
UAS up	192	0	0	0	53
SES down	0	0	0	0	73
SES up	0	0	0	0	53
ES down	6	17688	34	537	3397
ES up	111	0	0	0	0
LOS down	0	0	0	0	0
LOS up	0	0	0	0	0
ECS down	0	17342	3531	0	0
ECS up	0	0	1	0	0

Line 6. in Table III is a typical example of a line where one of the ADSL2+ transceivers is working incorrectly. This can easily be concluded on the basis of a large number loss of xDSL transceivers synchronization with a very small number of errors and the seconds in which they occurred. It is not possible to have 13 loss of modem synchronization on the correct ADSL2+ modem with only six registered ES.

Line number 7. in Table III is an example of a line where it is possible to detect the cause of the issue using the data on physical layer parameters, but in this case, it is justifiable to assume what steps to take to address these problems. It is clear that there are phenomena on the xDSL line that significantly cause line errors. The left column represents the state of the line when there was a significant degradation of IPTV QoS parameters. Right column reports the state of the line when the degradation of IPTV QoS parameters practically eliminated. It is most likely that a significant contribution to the errors on the line is given by a significant level of broadband noise, i.e. the influence of adjacent lines in the same cable.

According to the parameters in the left column of the report: ECS and ES it is noted that there were large number of FEC codes and a large number of CV codes. However, from the SES value, it can be concluded that line errors, although very numerous for a period of 24 hours, are not errors that occur in bursts, but less intrusive individual errors. On this basis, it can be reasonably assumed that the application of the additional correction coding will give positive effects. Using codewords with multiple redundant bytes on such lines, very often changes the structure of FEC and CV significantly, i.e. ECS and ES in favour of FEC and CV. This is very clearly seen from the right-hand column when, after additional correction coding, there are very few unremoved errors on this line. In other words, the problem was resolved without the need to measure electrical parameters through handheld measuring instruments and without any physical actions on the line, i.e. practically only by using application solutions.

Line number 8. in Table III is an example of lines where large number of errors are noticeable that occur more significantly over certain periods of the day and exclusively on the downstream. This is an example of a line with a very pronounced FEXT effect (Far End Crosstalk). However, if we compare parameters of the line FEC, CV, SES, ES and ECS for current (current 10h and 39 min) and history (24 h before the start of the period marked as current), whereby the counters for the parameters from the current period start at about 01:50 h, it is clearly noticeable that the number of line errors in full 24 h is much higher than the number of errors in the current 11 h. These parameters may indicate one of the two possible causes of this issue. The first possibility is that another xDSL line effects this line, which is inactive for a certain part of the day. Such lines are, e.g. xDSL lines through which only Internet access is realized. Lines that transmit IPTV and VoIP services are active throughout the entire day. Another possibility is that there is a xDSL modem of insufficiently quality on the line, which works improperly in the night hours. The reason for this can be a higher load on the power grid and the possibility that the power supply voltage is significantly lower than the required 220 V.

Most observations and conclusions described in the example of eight xDSL lines, which represent a significant number of other and similar xDSL lines with similar causes of degradation of IPTV QoS parameters from the real system in practice, can be presented in the descriptive observations and conclusions presented in Table IV [6]. With the wider application of such test scenarios and with recording the large number of observations and the correlations between the physical layer and electrical parameters, conditions are acquired that with the growing reliability it can be reasonably assumed or known for sure which occurrences on a physical layer xDSL line cause the degradation of IPTV QoS parameters based only on knowing of physical layer parameters.

TABLE IV
PHYSICAL LAYER PARAMETERS USE OF

Physical layer parameters	Existing occurences	Non-existing occurences
Max. rate OK (in respect to loop length)		Resistive fault(s) (series and/or shunt)
Low max.rate; high line attenuation	Resistive fault(s) (series an/or shunt)	
Number of CV, FEC, ES, ECS; Small of SES and LOS on DS; max. rate OK	Wideband noise; splits loops	Impulse noise; Series and shunt resistive fault(s)
Number of CV, FEC, ES, ECS, SES on US and DS; max. rate OK	Interference from power cables and/or crosstalk	Wideband noise; Series and shunt resistive fault(s)
Number of CV, FEC, ES, ECS; Small of SES and LOS on DS in the afternoon or night; max. rate OK	Wideband noise from adjacent xDSL lines; Unstable power supply at night	Impulse noise; Series and shunt resistive fault(s)
Number of IA; Small of CV, ES, ECS, SES, LOS	Poor and unstable wire contacts	Impulse noise; wideband noise; Resistive fault(s)
Number of SES, LOS; Small of CV, FEC, ES, ECS; Max. rate OK	Impulse noise; shunt fault(s) towards adjacent loops	Series fault(s)
Number of IA; no CV, FEC, ES, ECS, SES, LOS	Incorrectly operating of xDSL transceivers	No resistive faults; neither wideband nor impulse noise

VI. CONCLUSION

The problem of degradation of IPTV QoS parameters can be solved in least two different ways. In order to eliminate the degradation of IPTV QoS parameters, in certain situations in practice, some quite efficient solutions, that do not require any physical interventions on the physical layer xDSL line, are developed. However, such solutions do not eliminate the cause of degradation of QoS parameters, but only enable QoS parameters to return to the recommended values by processing the signals and packets. For almost all such solutions, there must be some unwanted price, whether it's a reduced bit rate of data transmission, or there are unwanted minor or larger delays in service delivery, which can be negatively reflected on IPTV QoE. But regardless of everything, the fact is that such solutions cannot be useful in a significant number of frequent cases in practice.

In the real system in practice very often it is necessary to access to very detailed troubleshooting tests in order to detect and eliminate the actual cause of the degradation of IPTV QoS parameters on xDSL lines. For one part of the troubleshooting tests that need to discover the existence of degradation of IPTV QoS parameters and physical layer parameters of the xDSL transceiver, highly reliable solutions have been developed. However, the detection of the actual cause of degradation of IPTV QoS parameters in practice is still insufficiently well resolved. Such solutions are always being worked on through appropriate technical reports and appropriate recommendations. But the solution that is sufficiently efficient for all possible circumstances has not yet been found.

For reliable detection of the causes of degradation of IPTV QoS parameters in most cases it is necessary to perform long-term measurements of electrical parameters. These measurements are the most critical step in troubleshooting testing. However, there is a possibility that the proper interpretation of a large number of detailed values of the physical layer parameters of xDSL transceiver can make the measuring of electrical parameters more time-efficient. The requirement for this are the significant experiential insights gained in practice in such a way that, for an enormous number of xDSL lines, the correlation between some typical values of the physical layer parameters of the xDSL transceivers and the corresponding values of the electrical parameters of the copper pair is made. In this way, for certain characteristic values of the physical layer parameters of the xDSL transceiver, it is often possible to assume which electrical parameters are not within the required values. In other words, it is possible to reasonably assume or reliably know which occurrences on a physical layer of xDSL lines are causing the degradation of IPTV QoS parameters. This is the main way to reduce the number of electrical parameters to be measured. And reducing the number of electrical parameters shortens the time of performing troubleshooting testing.

These observations, based on the already developed test capabilities and test capabilities that are used in practice, can often have significant practical benefit. Of course, such solutions will not be able to give the desired results in all circumstances. But, also, some of the other already developed solutions and test scenarios do not give the desired results in all possible circumstances in practice.

References

[1] "Tr-126: Triple-play service quality of experience (QoE) requirements," technical report, DSL Forum, December 2006.

[2] "Tr-198: Dqs:dqm systems functional architecture and requirements," technical report, Broadband Forum, November 2012.

[3] "G.996.2: Single-ended line testing for digital subscriber lines (DSL)," ITU-T recommendation, ITU, August 2013.

[4] "Tr-286: Testing of metallic line testing (MELT) functionality on xDSL ports," technical report, Broadband Forum, March 2014.

[5] "Triple-play service deployment-a comprehensive guide to test, measurement, and service assurance," white paper, JDS Uniphase Corporation, Milpitas, CA, USA, October 2007.

[6] N. Škaljo, A. Begović, E. Turajlić, and N. Behlilović, "On using of physical layer parameters of xdsl transceivers for troubleshooting," in *Proceedings of 24rd International Conference IWSSIP*, (Poznan, Poland), pp. 1–4, May 2017.

[7] N. Škaljo, A. Begović, and N. Behlilović, "A possibility of estimation of iptv qos parameters by using DSL transceivers physical layer parameters," in *Proceedings of 36rd International Convention MIPRO*, (Opatija, Croatia), pp. 410–413, May 2013.

[8] "G.997.1: Physical layer management for digital subscriber line DSL transceivers," ITU-T recommendation, ITU, June 2012.

[9] J. A. Andersson, M. Kihl, S. Höst, and D. Cederholm, "Impact of dsl link impairments on higher layer qos parameters," in *Proceedings of Swedish National Computer Networking Workshop*, (Sweden), pp. 95–98, January 2012.

[10] I. Pinilla, E. Areizaga, and J. Rius, "Quality multimedia distribution through resource management and performance monitoring over dsl networks," in *Proceedings of 2008 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, pp. 1–4, March 2008.

[11] N. Škaljo, A. Begović, M. Hadžialić, and N. Behlilović, "An efficient troubleshooting testing scenario for iptv over dsl: preliminary discussion," in *Proceedings of 21rd International Conference IWSSIP*, (Dubrovnik, Croatia), pp. 139–142, May 2014.

[12] N. Škaljo, A. Begović, and N. Behlilović, "An efficient troubleshooting testing scenario for iptv over dsl: practical examples," in *Proceedings of 22rd International Conference IWSSIP*, (Dubrovnik, Croatia), pp. 233–236, September 2015.