DIAGNOSIS OF FAULTS AND DISTURBANCES IN FIXED ACCESS TELECOMMUNICATION NETWORKS THAT DELIVER TRIPLE-PLAY SERVICES

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REZIME

Faults and disturbances in the fixed access telecommunication networks made of symmetrical copper pairs through which triple-play services are delivered, are common occurrence. These faults and malfunctions can do a greater or lesser extent affect the QoS (Quality of Service) of triple-play services, especially IPTV (Internet Protocol TV) which is far most demanding service. This paper will describe some of the existing methods and tools for the detection of faults and disturbances. Also, this paper will describe some new test scenarios designed for more successful detection of faults and disturbances in order to allow higher quality of triple-play services.

1. UVOD

For the purposes of delivery of IPTV (Internet Protocol Television) services, by far the largest number of existing telecom operators in Europe and the world, who have been delivering POTS (Plain Old Telephone Service) service to its customers for decades, have decided to take maximum advantage of their existing infrastructure of access networks made of cables with symmetrical copper pairs. Even before the introduction of IPTV services, for the purposes of delivery of Internet services and data transmission, DSL (Digital Subscriber Line) lines have already been enormously developed. DSL lines at the physical layer of the OSI communication systems were ideal base for the delivery of IPTV services. As a result, we have a situation where currently approximately 70% of IPTV services in the world is being delivered through different variations of DSL lines, such as ADSL2 + (Asymmetric DSL), VDSL (Very High Bit Rate DSL) and VDSL2 lines.

However, this method of implementation of IPTV services, apart from maximizing the usage of existing infrastructure that was used for decades, brings some risk with it. By this we mean very real potential for problems in the functioning of IPTV services. These problems can be caused by any segment of the entire telecommunication system, wherein the access networks are only one of the segments of this system [1]. It is a widespread opinion that the access networks and the occurrence on them cause the greatest number of problems in the functioning of the IPTV services.

Also, within access networks themselves, there are many elements of access network that can cause problems in the functioning of the IPTV services. There are two basic phenomena in access networks that create these problems. These are the effect of faults and disturbances that act individually or combined. In accordance with previously written, it is necessary to have the appropriate tools and procedures for the efficient diagnosis of faults and disturbances.
This paper is overview of some prior papers of these authors. This paper mainly discusses the diagnosis of faults and disturbances in the access networks in which the IPTV services are transmitted over the DSL lines [1]. Under the term DSL lines we mean symmetrical copper pairs and DSL transceivers on both sides of copper pairs.

2. PARAMETERS OF IPTV SERVICE

Problems in the delivery of IPTV services are manifested in different ways on the user side and on the telecom operators side. Regardless in which segment of the entire telecommunication system problems arise, user experiences this service subjective. IPTV services from the user's point of view is described by subjective QoE (Quality of Experience) indicators [2]. Some of these indicators are following:

- service accessibility,
- pixelation,
- frame freezes,
- edge distortion,
- blue screen,
- channel change patency pause.

For this subjective concept of service, there is a fairly effective objective way to assess performances of the entire telecommunications network that deliveres services, which directly affect the user's experience of services. In other words, there are QoS (Quality of Service) measurable parameters of the network at the level of IP packets and video packets. Basically, the most important QoS parameters at the level of the packet are [3]:

- throughput,
- packet loss,
- delay,
- jitter

Table 1. Recommended transport layer parameters for satisfactory QoE for MPEG-2 SDTV [3]

Bit rate (Mb/s)	*Delay (ms)*	*jitter (ms)*	*Maximum duration of a single error (ms)*	*Corresponding loss period in IP packets*	*Loss distance*	*Corresponding average IP video stream packet loss rate*
3,0	*<200*	*<50*	*≤16*	*6 IP paketa*	*1 error event per hour*	*≤ $5,85x10^{-6}$*
3,75	*<200*	*<50*	*≤16*	*7 IP paketa*	*1 error event per hour*	*≤ $5,46x10^{-6}$*
5,0	*<200*	*<50*	*≤16*	*9 IP paketa*	*1 error event per hour*	*≤ $5,26x10^{-6}$*

Apart from these three main QoS parameters, there are also some other measurable parameters, which can influence the QoE parameters, such as: error indicator, continuity error, PCR (Program Clock Reference) jitter, PSI (Program Specific Information) data error, IGMP (Internet Group Management Protocol) latency etc.

However, although there are very effective mechanism for testing the IPTV QoS parameters, it still does not mean that there are effective mechanisms for diagnostics of phenomena that cause problems in the functioning of the IPTV services. It depends on which segment of the entire telecommunication system causes noted problems. If testing QoS parameters reliably establishes that the problems in the delivery the IPTV services occur in the access network then, almost as a rule, it is necessary to apply several different tests to reliably establish which element of the of access network is causing the problem and its spatial position [1].

3. TEST SEGMENTS ON IPTV SERVICE

If the IPTV services are delivered to end users through a DSL line, then in the purpose of diagnosting the cause of the problem at least four different types of testing should be performed. These tests are classified into four different test segments (Figure 1).

With the help of testing QoS parameters on test segments 3. and 4. it is being determined which segment of the entire telecommunications system causes problems detected. If it is found that this segment is the access network, then in most cases the test segments 1. and 2. need to take an additional three types of testing. On the test segment 1. it is usually necessary to carry out two types of tests.

Testing QoS parameters on test segments 3. and 4. very reliably determine, which segment of the overall telecommunication system causes the perceived problems in the functioning of the IPTV services. These tests are performed at the level of IP packets and video packets.

Testings on the test segment 2. also quite confidently confirm that the problem is in the domain of access networks, specifically in the domain of DSL lines [4]. Also, testings on this segment determine the time intensity of occurrence of perceived problems, which is very important for testing that must be done on the test segment 1. It is very important to note that testings on test segments 2., 3. and 4. are centralized and automated.

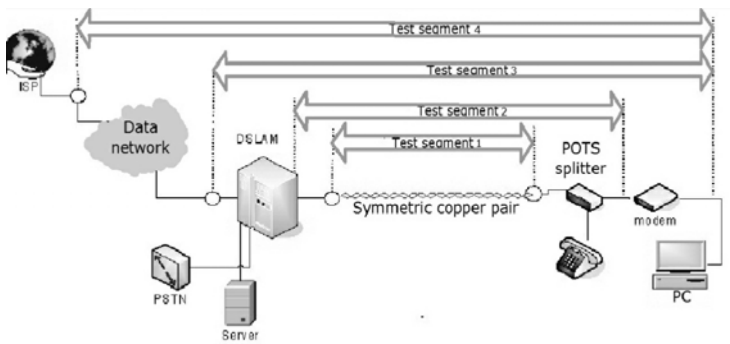

Figure 1. Test segments on DSL systems

The parameters that are being tested in this test segment are called modem or physical layer parameters of the DSL transceiver. Some of these parameters are [5]:

- Actual line data rate,
- Maximum achievable rate,
- Output power,

- Signal attenuation,
- SNR (Signa to Noise) margin,
- FEC (Forward Error Correction) codes,
- CV (Code Violation) codes,
- Count of initialization attempts,
- Error seconds (ES),
- Error correction seconds (ECS),
- Severely error seconds (SES).

Reliability of the testing results on this segment in the dominant extent determines the efficiency of testing that will be performed on the test segment 1., and thus the efficiency of the overall diagnosis of the problem. One employee can independently perform daily testing on several dozen, or even close to a hundred, symmetrical copper wire pairs.

3.1. Testings on the test segment 1.

Testings on this test segment, ie diagnosis of faults and disturbances in fixed access networks are still dominantly manuel and not centralized. In other words, these testings are done by hand-held measuring instruments and departures of employees out to the field and in most cases up to the end services user. Depending on the test results on the test segment 2. and the occurrence to which this tests will indicate, in a significant number of cases, testings on the test segment 1. can be very time-consuming.

Parameters that are being tested in this test segment are called electrical parameters of symmetrical copper pair. Some of these parameters that need to be measured most commonly are [2]:

- foreign voltage (DC and AC),
- insulation resistance of copper pair,
- DC loop resistance,
- loop length,
- longitudinal balance,
- near end crosstalk (NEXT),
- far end crosstalk (FEXT),
- wideband noise,
- impulse noise,
- impedance of line,
- return loss.

Two types of testings are performed in the test segment 1. While testings on the segment 2. should point out what are the phenomena in the domain of DSL signals that degrade QoS parameters, the first type of testing on segment 1. needs to point out what are the electrical parameters that cause degradation of the DSL signal. On the basis of detailed testings of electrical parameters it can be determined which phenomena in the access networks have created problems in the functioning of of IPTV services, ie whether these problems create faults or disturbances or the combined effect of both phenomena.

Fault is a result of permanent cancellation or change of one or more elements of the telecommunications cable or pair, whereby it comes to greater or smaller changes of one or more primary parameters of copper pairs. There are several types of defects. Under the term disturbance on the DSL local loop we imply the occurrence that, on the observed copper pair, has the character of disturbing the useful signal by undesirable signal, and in doing so, the observed pair may, or may not, have easily measurable and visible fault. Also, there is more than one type of disturbance.

The first kind of testing on the test segment 1. requires the participation of at least two, and sometimes three employees. If circumstances on a DSL line require measurement of all of the listed electrical parameters, then these two (or three) employees can measure the maximum of 5 or 6 symmetrical copper pairs daily. Although the first type of testings on this test element lasts long, the process of fault and disturbance diagnosis does not end with these measurements. As already written, this first type of testing should only determine what phenomenon, ie whether faults or disturbances cause a malfunction of the IPTV service.

In addition to the previously mentioned tests, for a full diagnostic of faults and disturbances other types of testing on the test segment 1. must be done, ie spatial location of the points on the access network where faults or disturbances occur. While there are more or less successful methods for measuring spatial location of faults, for spatial location of disturbances there are no reliable methods of measurement.

The practice and theory, from the time when only POTS services were transmitted over symmetrical copper pairs, know only two types of measurement methods for spatially locating faults. These methods are more presented in [6]. Both have their advantages and disadvantages and field of application. Those are the following measurement methods:

- bridged methods of fault location,
- impulse method of fault location.

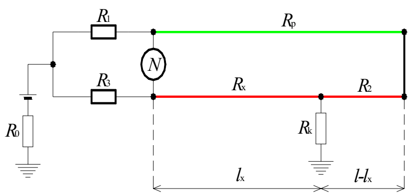

Figure 2a Bridged methods of fault location

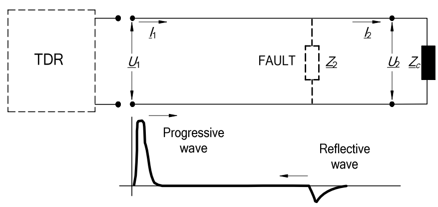

Figure 2b Impulse method of fault location

For bridged methods of fault location, from condition of bridge balance, after basic transformations we obtain:

$$l_x = \frac{2R_3}{R_1 + R_3} \cdot l \qquad (1)$$

For impulse method of fault location, reflection coefficient of voltage is defined as:

$$\underline{r} = \frac{\underline{U}_r}{\underline{U}_d} = \frac{\underline{U}_2 - \underline{Z}_c \underline{I}_2}{\underline{U}_2 + \underline{Z}_c \underline{I}_2} \quad \text{or} \quad \underline{r} = \frac{\underline{Z}_2 - \underline{Z}_c}{\underline{Z}_2 + \underline{Z}_c} \qquad (2)$$

Both of these measurement methods are, in fact, called measurement methods for approximate determination of fault on symmetrical copper pairs. This only indicates that this type of testing, depending on the intensity of faults, can be significantly more time-demanding than the first type of testing on the first test segment. A result of this kind of testing is quite often a need for performing various construction or installation work (excavation of cables, processing extensions on them, replacing segments of cables and various other operations on many elements of the access network).

It is clear that both types of testing on test segment 1. represent a "bottleneck" in the process of diagnosis of problems in the delivery of IPTV services. In these processes, by far the most time is spent on detecting the real cause of the problem and its spatial position, and after that, in most cases, the process of eliminating the problem becomes routine.

3.2. The using of appropriate test scenarios

For diagnosis of faults and disturbances to be successful, it is necessary to apply the appropriate test scenarios in practice. Under the term test scenarios we mean defining all of parameters that need to be tested, the order of these tests, as well as a way to collect test results. One test scenario reached by the authors of this work through their practical experience will be presented in this paper [7].

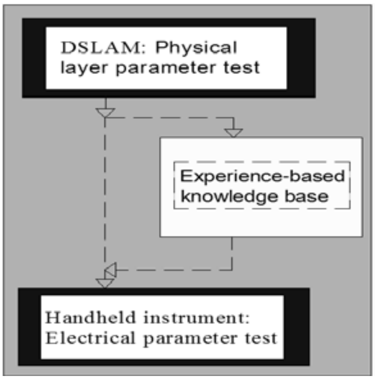

Figure 3. Efficient Troubleshooting testing scenario

Mentioned test scenario looks like on Figure 2. Some of the features of this test scenario, unlike other existing test scenarios [2], are:

- Very reliable assessment of whether the problems on the service are caused by the events on DSL lines, and through the detection of the presence and number of errors, and their structure.
- Observation of the line that transmits the service in which problems are identified in quite a long time intervals. This leads to a secure detecting of consequences of the events on copper pair, which occur only occasionally (intermittent broadband and impulse noises).
- The ability to evaluate the nature of the problems that occur on copper pair, which, to a large extent, can facilitate the process of manual measuring by measuring instruments.

The main improvements achieved by applying such a test scenario consist in possibility to estimate the causes of problems by knowing the physical layer parameters that describe the behavior of DSL lines in long periods of time. The gathering of these parameters is carried out by centralized monitoring platforms, rather than using hand-held measuring instruments what other test scenarios insist on. This way, the technical staff that will carry out the testing by handheld test instruments, has very reliable information about the existence of problems on DSL lines, and fairly reliable knowledge about the manifestations of it, and in a significant number of cases quite reasonable assumptions on which phenomena are causing problems in the functioning of IPTV service. In some cases, a significant number of problems will be able to be detected and located, and thus eliminated without the need for measuring any electrical parameters [7].

How do we come to the assumption that certain phenomena on DSL lines create problems in the functioning of IPTV?

We start from the fact that the values of the physical layer parameters of DSL transceiver far the most determine values of electrical parameters of copper pairs. Then, we start with some empirical knowledge, which can be explained by the theory, that some parameters of the physical layer, or some combination of the physical layer parameters are determined by some electrical parameters or some combination of electrical parameters. And, when we know, or reasonably assume what are those electrical parameters, then it is quite easy to know or assume which phenomena on copper lines or DSL lines cause problems in the functioning of the IPTV service. This way we acquired conditions that, in a significant number of cases, we can quickly repair any detected problems [8].

Table 2. Examples of characteristic results

Line number		line 1	line 2	line 3	line 4
Line length (m)		1402	451	1273	1328
Line rate (kb/s)	down	6170	4819	3470	6063
	up	872	771	447	903
Maximum attainable bit rate (kb/s)	down	16204	22560	4652	16420
	up	2252	1695	495	1208
Signal attenuation (dB)	down	27,6	23,6	39,6	21,3
	up	21,3	21,2	52,5	10,8
SNR margin (dB)	down	17,5	32,1	6,0	10,0
	up	16	13,1	6,1	11,8
FEC (Forward error correction) codes	down	5291508	20218	2	0
	up	1771	107282	8	0
CV (Code violation) codes	down	2486	26	8	6
	up	1797	19647	14	1
Count of initialization attempts		0	28	1	13
UAS (Unvailable seconds)	down	0	894	38	192
	up	0	954	48	192
SES (Severely Errored Seconds)	down	0	6	0	0
	up	0	2186	0	0
ES (Errored Seconds)	down	277	20	8	6
	up	1371	5564	15	1
LOS (Loss of Signal)	down	0	3	0	0
	up	0	0	0	0
ECS (Error Correction Seconds)	down	80790	416	0	0
	up	1120	5971	0	0

On table 2, through four examples of detailed reports of physical layer parameters collected through control unit of DSLAM (DSL Access Multiplexer) devices we will demonstrate the usability of the application of this new test scenario on the real system in practice. We are talking about ADSL2+ (Asymmetric DSL) lines, and data for the largest number of parameters are related to the continuous period of 24 hours. The results from table 2. already presented in [8].

For line 1., given the large number of FEC codes and CV, and ES and ECS seconds, this is the line on which high level of broadband noise is present. And, the line itself is likely to be crossed with another near a DSL line. Or, possibly, there is bad insulation resistance towards a neighboring DSL line.

For line 2., this possibly could be an example crossed pairs with another DSL line whose downstream overlaps with the upstream of this line.

For the line 3., these results are shown only on lines that have very pronounced serial resistive faults, and measurements through TDR (Time Domain Reflectometer) instruments should instantly start, but without measurement of any electrical parameters.
Line 4. is a typical example of the lines on which there is an improper functioning of one ADSL2+ transceiver.

4. CONCLUSION

Delivery of IPTV services over DSL lines enables telecom operators very quick and economically feasible way to implement this service. Since DSL involves the usage of existing infrastructure of access networks, with, of course, certain investments in active access equipment and terminal equipment on the user side, it is obvious why this is the dominant technology of delivery of broadband services, and consequently of IPTV services.

However, this technology carries quite a higher risk than "the competitive" technology based on optical fiber cables in access networks in terms of occurrence of possible failures, especially external electromagnetic influences. In this regard, it is necessary to develop adequate mechanisms for detecting faults and disturbances in landline networks made of cables with symmetrical copper pairs. This work briefly described these procedures.

It could be read that the detection of faults and disturbances that cause problems in the delivery of IPTV services in general is not an easy job. Depending on the type of the identified problems, the process of detection of problems causes can be a very long process in which, in fact, by far is the most difficult to establish which phenomenon, ie fault or a disturbance or the simultaneous presence of both, causes problems in the functioning of IPTV services. Given that this is a very sensitive segment of this method of delivery of IPTV services, it is obvious why the appropriate recommendations of the relevant standards bodies have not yet given their final word. In this regard, it is constantly being worked on the upgrade of various recommendations in this area in order to define new test possibilities that need to be equipped with an active network elements, both on the telecom operator side, and on service user side.

5. REFERENCES

[1] Broadband Forum Technical Report TR-160: IPTV Performance Monitoring, November 2010,

[2] JDSU: Triple-Play Service Deployment - A Comprehensive Guide to Test, Measurement, and Service Assurance, JDSU, Oktober 2007,

[3] DSL Forum Technical Report TR-126: Triple-play service Quality of Experience (QoE) requirements, December 2006.

[4] DSL Forum Technical Report TR-005: ADSL Network Element Management, March 1998,

[5] ITU-T Recommendation G.997.1: Physical layer management for digital subscriber line (DSL) Transceievers, ITU-T, June 2012,

[6] Škaljo N., Begović A., Behlilovic N., „Methods of Locating Galvanic Faults in Symmetrical Copper Pair Cables in DSL Systems“, ELMAR, Zadar, September 2009, pp. 119-122,

[7] Škaljo N., Begović A., Goran N., „Simplified Scenario of Testing DSL Lines Delivering Triple Play Services”, TELFOR, Beograd, November 2012, pp. 288-291,

[8] Škaljo N., Begović A., Behlilovic N., Hadžialić M., „An Example of Efficient Troubleshooting Testing Scenario for IPTV over DSL“, IWSSIP, Dubrovnik, may 2014, accepted for publication,