TR-127 Ensures Quality of Service for IPTV

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Introduction

TR-127 is a Technical Report developed by the Broadband Forum to ensure the highest quality delivery of voice, data and video services [Triple Play] by maximizing the interoperability of splitters and in-line filters with Digital Subscriber Line Access Multiplexers [DSLAMs] and modems.

In this environment, Central Office [CO] and Customer Premise Equipment [CPE] splitters are tested with DSLAMs and modems as part of a full system test, as opposed to being tested in isolation. By doing so, the splitters can be designed to ensure the highest quality of video service without interruption from the telephone service with which it shares the telephone line. . Without TR-127 testing during the design phase there is no way to ensure the splitters are immune to interruptions caused by the telephone ringing, the telephone going Off-Hook or On-Hook, or due to the telephone being answered while ringing, referred to as Ring-Trip.

Delivering Triple Play Services to the Home

Telephone companies who just offered standard voice services via POTS [Plain Old Telephone System] were able to add data services via DSL [Digital Subscriber Line] on the same twisted pair copper telephone line. The cable TV companies also started offering data through their video service over their coax cable lines. In addition, the cable guys added telephone services via Voice Over Internet Protocol [VOIP] and so offered the full “Triple Play” package to customers. The telephone companies, to be competitive with the cable companies, offered Internet Protocol Television [IPTV] to complement their data and voice services and so compete with the cable companies offering “Triple Play.” However, in order to compete effectively, the quality of the video provided by the telephone companies has to be to the same level as that of the cable and satellite companies.

Best Effort versus Guaranteed Services

Data is sent over wires in small bursts called packets. These packets of data are affected by electrical noise and other electrical interference from the environment. This noise and interference causes some packets of the data to be lost. Lost packets of data are measured by the code violations or Cycle Redundancy Check [CRC] of the data frame. How these lost packets of data are handled depends on the transport protocol used to send the data over the copper lines.

Data sent by the telephone companies uses a protocol known as HTTP, which in turn uses the TCP protocol for its transport layer. The delivery of such data is guaranteed, in that if a packet of data is lost, then it is re-sent. For data, such as documents, this is good because the delivery of all the packets of data is important and is not so time dependent. For example, while browsing the internet it would not be good to click onto your favorite on-line newspaper and find some of the text missing. However, you don’t mind waiting a little longer for the page to down load properly.

For video feeds, such as IPTV, there is no time to re-send the lost packets of data. Hence the video applications use the UDP transport protocol. This is described as a best effort service in that the applications send data from server to client as fast as they can, without checking to see if the packet of data is lost or not. If some packets are lost then they are not re-sent. These lost packets manifest themselves on your TV screen as black spots of missing data called pixelization. Although it can be argued that techniques such as Forward Error Correction and packet interleaving can try to re-create the lost packets and minimize this video data loss, these techniques are not sufficient to prevent pixelization in all cases.

IPTV Platform

One of the main data compressing protocols for delivering video services, such as IPTV, is Moving Pictures Expert Group-2 (MPEG-2). Downstream speeds and acceptable packet loss for Standard Definition TV (SDTV) on MPEG-2 ranges from 3-5 megabits per second (Mbps) with a packet loss of approximately 1 packet in every 100,000 packets sent. High Definition Television (HDTV) on MPEG-2 has downstream speeds between15-18 Mbps with a packet loss of approximately 1 packet in every 1 million packets sent.

Note: A typical IP data packet contains seven 188-byte MPEG-2 packets. So the loss of a single IP packet is a loss of over 10,000 bits. To attain an IP packet loss of 1 packet in every 1 million sent means that a maximum of 1 bit can be lost in every 10 billion sent.

FTTC Architecture

In order for telephone companies to achieve these data rates, a combination of Fiber-To-The-Curb (FTTC) and Very High Speed Digital Subscriber Line 2 (VDSL2) is required.

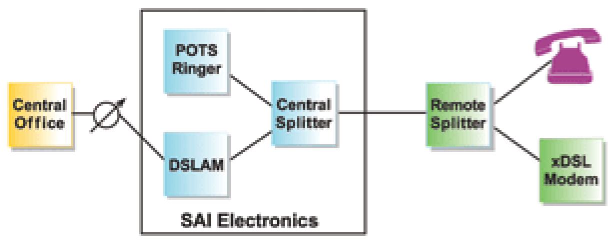

Figure 1: Typical FTTC Architecture

FTTC architecture originates with fiber from the Central Office to the Service Access Interface (SAI). The subsequent copper local loop from the SAI electronics to the subscriber is no longer than 1000 meters in most cases. Currently, the highest performance DSL technology used for delivering Triple Play is VDSL2. Typically, VDSL2 transmission over a 1000 meter line can provide 29 Mbps downstream and 5Mbps upstream.

Data Loss Due to Telephony Services on IPTV Networks

To recap, telephone companies now provide voice, data, and video services. Voice is the original analog telephone service. Data and video are part of the new digital services. These services are all sent down the same twisted pair copper line. Some loss in video data can be due to interference from the voice service on the line. The sources for these can be categorized as:

- Ringing Voltages
- Off-Hook: Telephone receiver is lifted
- On-Hook: Telephone receiver is replaced
- Ring-Trip: Telephone is answered during a ringing period

Ringing

The ringing signal from the CO is 90 volts AC RMS @ 20 Hz. Therefore the peak voltage of the ringing signal is actually 127 volts. The battery from the telephone company's CO provides -48 volts DC. The ringing voltage for the telephone is a 90 volts RMS AC signal sitting on a DC Voltage of -48 volts. Therefore the maximum positive voltage can be +127- 48 = +79 volts and maximum negative voltage can be -127- 48 = -175 volts. Both CO and CPE splitters are subject to these voltages during ringing.

Off-Hook / On-Hook
When the telephone receiver is lifted, in the absence of ringing, the splitters are subject to the DC battery feed voltage of -48 volts. The On-Hook impedance of the receiver is in the region of 4000 ohms. Hence, current flowing is small [<1 mA]. The Off-Hook impedance of the receiver is a minimum of 200 ohms and the DC current flowing is in the region of 100 mA. So going off-hook, combined with the instantaneous voltage change, produces an instantaneous current surge that the splitters must contend with.

Ring-Trip
When the telephone receiver is lifted at the negative peak of the ringing voltage an instantaneous voltage peak of -175 volts is received at the splitter. This condition is known as ring-trip because the ringing signal is stopped [or tripped] when the end user picks up the telephone. Again the splitters are subject to these voltages spikes.

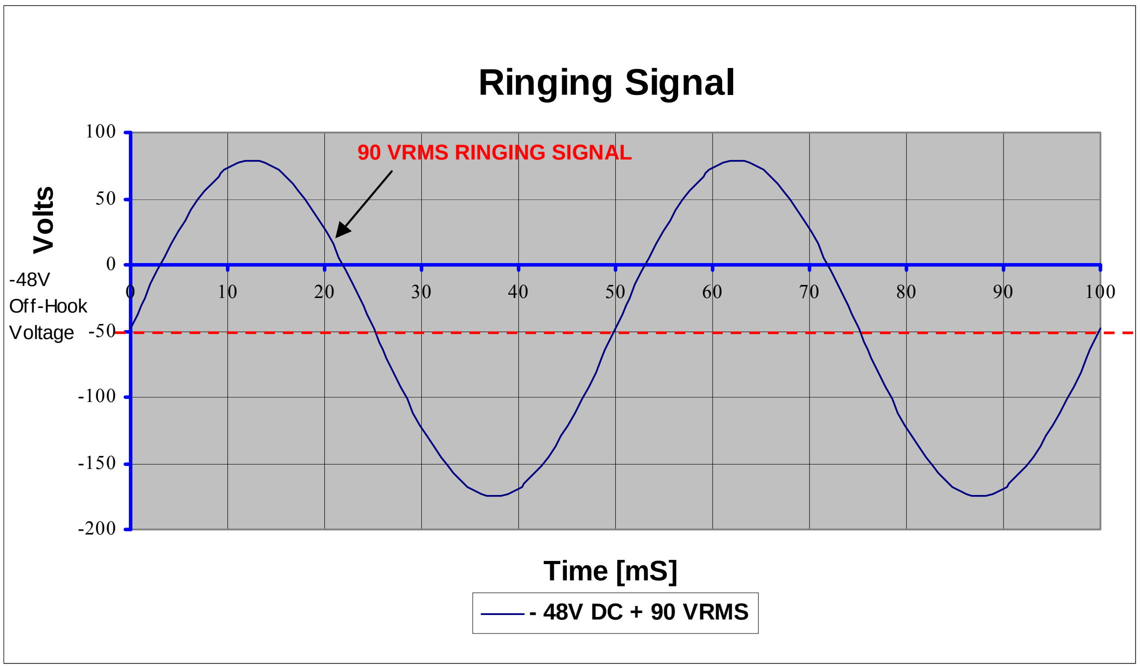

Figure 2: 90V RMS Ringing Signal Superimposed on -48V DC

How the splitters perform during ringing, On-Hook & Off-Hook transitions, and Ring-Trip has a big influence on the quality of the video services. Some low grade splitters can saturate in the presence of these high voltages and currents, which means they no longer prevent noise from interfering with the data packets sent at the same time. This causes data corruption and packet loss. High grade splitters, like those offered by Pulse in the SmartER range, do not saturate as they are designed to meet TR-127.

TR-127 Ensures Quality of Service using High Grade Splitters

So with the requirement from the telephone companies for high grade splitters capable of delivering high quality Triple Play services came the need for the industry to find a method to test the splitters in a real life situation in order to determine the performance of these splitters. The Broadband Forum gathered leading experts from telephone companies, modem suppliers and splitter manufacturers. This included a representative from Pulse. Working together this group developed TR-127. This standard defines the basic concepts for dynamic testing of the CO and CPE splitters with the DSLAMs and modems as a full system. If problems occurred when the splitter was tested in a full system with respect to data loss or poor data rate performance, it was a lengthy procedure to modify the splitter design to fix the problem. This was because the splitter manufacturers had no defined method to verify changes to the design of the splitters at a system level. With TR-127 compliance testing during design, splitter manufacturers can now ensure high quality splitters, saving the telecom companies valuable development time and optimized system performance for Triple Play.

TR-127 Test Features

The TR-127 standard issue 1 was officially published in May of 2009. It defines specifications and agreed procedures for testing CO and CPE splitters with DSLAMs and modems. These test procedures define methods to ensure DSLAMS and modems are error free before test and methods to ensure baseline or "known working" splitters can perform each test within acceptable criteria before testing of the "splitter under test" begins. In addition to determining the maximum net data rates for a splitter over a given cable loop length, basic tests also include testing the system in the following conditions:-

- When the telephone is in the steady ON or OFF hook state
- When the telephone is experiencing a continuous ringing signal
- When the telephone is experiencing a cadence ringing signal
- When the telephone receiver is being lifted when no ringing signal is present [ON to OFF Hook transition]
- When the telephone receiver is being lifted when a ringing signal is present [Ring-Trip].

TR-127 includes full specifications for all pieces of test equipment that are required for testing including the:

- Ringing generator,
- DC battery feed,
- Test loops, both real cable and simulators
- Noise generators
- DSLAM and modem features
- Cable specifications and loop lengths to be used during test, with separate specifications for ADSL2+ and VDSL2
- DSLAM and modem settings for Noise Margin, Impulse Noise Protection [INP], delay and Max and Min Net Data Rates (NDR) for ADSL2+ and VDSL2 for Triple Play, HSI and in-line filter testing.

The standard also defines all POTS stationary and transient testing conditions including:

- On/Off Hook DC feed conditions
- AC continuous ringing and cadenced ringing signals,
- AC and DC impedance modelling
- CO POTS models, including models to allow injecting of ringing signal at every 6 degrees at the CO end.
- DSL friendly and unfriendly ringing
- Ring-Trip modelling at the CPE end, including methods to allow removal of the ringing signal at every 6 degrees.

Finally, TR-127 also provides for detailed pass/fail criteria based on data loss CRC check, NDR, and Noise. The strictest acceptance criteria are reserved for Triple Play splitters, of which Pulse's SmartER range of splitters pass fully for VDSL2.

Implementing TR-127 Testing

Pulse has a fully compliant TR-127 test facility. This allows Pulse to test its splitters for compliance to the standard for older ADSL2+ and the latest VDSL2 applications.

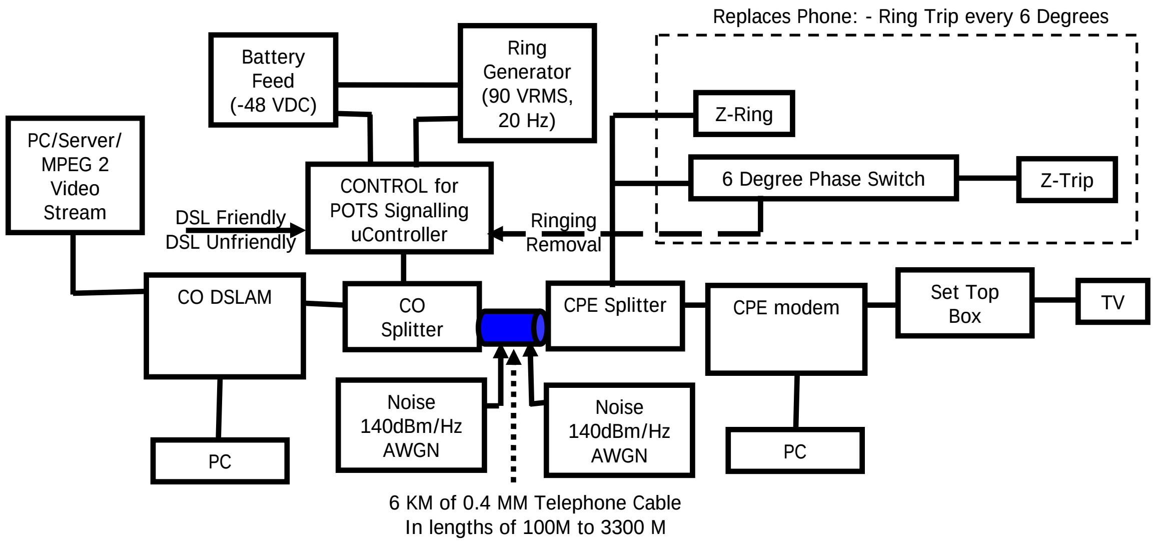

Figure 3: TR-127 Testing

The On-Off hook battery feed is provided by a DC power supply while a TR-127 compatible ringer provides the ringing signal. These are connected in a serial, unbalanced method as described in section 7.3.1.1 of TR-127. The microcontroller is used to control the POTS signalling. It allows for the ON and OFF Hook test conditions as well as injection of the Ringing Signal in a DSL friendly or DSL unfriendly method as described in section 7.3.1.2 of TR-127. The DSL friendly signal is injected at the zero cross-over of the ringing signal using the Clare Line Card Access Switch [LCAS] while the DSL unfriendly ringing signal is injected with a sliding 6 degree phase increment.

A PC can send MPEG-2 High Definition [HD] video stream into the DSLAM. The CO splitter combines the POTS and DSLAM signals and sends these over the required length of cable to the CPE splitter. For testing, 0.4 mm of actual telephone cable is used in lengths as defined for ADSL2+ and VDSL2 in Section 8.1.2 of TR-127, although various line simulators are available which comply with TR-127. The CPE splitter splits the incoming voice signal and data signal, sending the data signal (video) to the TV via the CPE modem andset-top box. The voice signal is sent to the TR-127 CPE model as defined in section 7.3.2. This CPE model includes an impedance for modelling the phone when it's on-hook [Z-RING] and an impedance for modelling the phone when it's off-hook [Z-TRIP]. The "6 degree Phase Switch" allows for Off-Hook transient testing and removal of the ringing signal in a sliding 6 degree phase as required by TR-127 Ring-Trip test, section 8.9 as well as an option for continuous Off-Hook.

Testing

TR-127 defines nine separate test procedures which are designed to test the splitter for both static and transient telephone conditions. One test is required for calibration. This ensures that the DSLAM and modem are error-free before starting to test. Two other tests are base line tests in which reference CO and CPE splitters are tested to ensure error free-operation of the overall system. The remaining six tests perform testing on the "splitter under test". Note that some of these tests have "sub" tests, bringing the total number of tests to fifteen. Also the use of a reference splitter is required in conjunction with the "splitter under test". If testing a CO splitter then it is required to use a reference CPE splitter. If testing a CPE splitter then a reference CO splitter should be used.

Each of the tests must be performed on each of the VDSL2 or ADSL2+ loops as required. For a VDSL2 splitter, all tests must be completed: 100m, 300m, 550m and 1000m. For an ADSL2+ splitter, all tests must be completed over 100m, 600m 1500m, 2500m, and 3300m.

Reporting

TR-127 defines acceptance criteria that ensure that all splitters will deliver error free Triple Play or HSI services. For each of the 9 tests over each of the loops defined for VDSL2 or ADSL2+, the following must be reported for both upstream and downstream:-

- Loss of modem synchronisation [not allowed during test]
- The number of CRCs [or Coding Violations] which indicate data packet lost.
- Net Data Rates
- The percentage Net Data Rate reduction of the system before and after the splitter is inserted
- Noise Margin

TR-127	Overall	Test Condition	CO	CPE	Loss Of Line Sync	NET DATA RATE [DS] (Kbps)	NET DATA RATE [US] (Kbps)	% NDR Change [DS]	% NDR Change [US]	Noise Margin [DS] (dB)	Noise Margin [US] (dB)	CRC [DS]	CRC [US]
8.2	PASS	Lab Calibration Test without Splitters	-	-	No	103992	97728	-	-	21	10.3	0	0
8.3.A	PASS	Continuous hook-state Test using baseline splitters	B8813NL	CP-V413S-A	No	103992	97728	0.0%	0.0%	21.1	10.4	0	0
8.3.B	PASS	Continuous hook-state Test using baseline splitters	B8813NL	CP-V413S-A	No	103992	97728	0.0%	0.0%	19.6	10.4	0	0
8.3.C	PASS	Continuous hook-state Test using baseline splitters	B8813NL	CP-V413S-A	No	103992	97728	0.0%	0.0%	19.8	10.4	0	0
8.4.A	PASS	Continuous hook-state test (with a Splitter as the DUT)	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	21.1	10.4	0	0
8.4.B	PASS	Continuous hook-state test (with a Splitter as the DUT)	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	19.6	10.4	0	0
8.4.C	PASS	Continuous hook-state test (with a Splitter as the DUT)	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	19.8	10.4	0	0
8.5	PASS	Continuous ringing test using baseline splitters	B8813NL	CP-V413S-A	No	103992	97728	0.0%	0.0%	21	10.4	0	0
8.6	PASS	Continuous ringing test (with a splitter as DUT)	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	21	10.4	0	0
8.7	PASS	Ringing with Cadencing Test (with a splitter as DUT)	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	20.5	10.5	0	0
8.8	PASS	On to Off-hook transition and back in absence of ringing	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	21	10.5	0	0
8.9	PASS	On-hook to Off-hook ring-trip transition	Example	CP-V413S-A	No	103992	97728	0.0%	0.0%	19.1	10.5	0	0

Figure 4: Example of Test Report for just the 100M loop for a VDSL2 splitter [tests 8.2-8.9].

TR-127	Overall	Test Condition	CO	CPE	Loss Of Line Sync	NET DATA RATE [DS] (Kbps)	NET DATA RATE [US] (Kbps)	% NDR Change [DS]	% NDR Change [US]	Noise Margin [DS] (dB)	Noise Margin [US] (dB)	CRC [DS]	CRC [US]
8.10-Test 1	PASS	Base Line-No Splitter	-	-	No	73207	15368	-	-	6.1	5.9	0	0
8.10-Test 2	PASS	On-Hook with Splitter	B8813NL	CP-V413S-A	No	73128	15232	-0.1%	-0.9%	6.1	5.9	0	0
8.10-Test 3	PASS	Off Hook with Splitter	B8813NL	CP-V413S-A	No	73128	15232	-0.1%	-0.9%	6.1	5.9	2	1

Figure 5: Example of Test Report for just the 100M loop for a VDSL2 splitter [test 8.10].

A portion of the test report is shown in figures 4 and 5. It can easily be seen that there is a significant amount of testing required to ensure that a splitter is fully compliant to TR-127.

Conclusion

In order for telephone companies to compete in today's market they must be able to provide the full package of Triple Play services to their customers. This means not only delivery of traditional telephone services, but also delivery of high quality data and video. To ensure high quality data and video delivery, focus must be placed on the splitters used at both the central office and in the customer premises equipment. Low grade splitters will saturate due to the voltages and current present in the telephony services. In doing so, this will interfere with the quality of the video delivered over the DSL line due to data loss. The customer will notice this when a phone rings and suddenly black spots and freeze frames will appear on the TV screen.

TR-127 is a standard designed to ensure that only high grade splitters, capable of delivering telephone services and high quality data and video, are used for high speed internet and IPTV applications. Pulse is leading the way by implementing this standard across its range of splitters. It already has a state-of-the-art TR-127 compatible testing facility. This has been used to test the SmartER series of splitters, which are fully compliant to TR-127 for VDSL2 applications. Looking forward, Pulse will use this facility to ensure that the next generation splitters are also fully compliant.

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Abbreviations:

AC	Alternating Current
ADSL2	Asymmetric Digital Subscriber Line version 2
AWG	American Wire Gauge
AWGN	Additive White Gaussian Noise
BW	Bandwidth
CO	Central Office
CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
DC	Direct Current
DS	Downstream
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer
FEC	Forward Error Correction
HD	High Definition
HDTV	High Definition Television
HIS	High Speed Internet
HTTP	Hypertext Transfer Protocol
INP	Impulse Noise Protection
IP	Internet Protocol
IPTV	Internet Protocol Television
LCAS	Line Card Access Switch
MPEG-2	Moving Pictures Expert Group-2
NDR	Net Data Rate
PC	Personal Computer
POTS	Plain Old Telephone Service
RMS	Root Mean Square
PSTN	Public Switched Telephone Network
TCP	Transmission Control Protocol:
US	Upstream
UDP	User Datagram Protocol
UTP	Unshielded Twisted Pair
VDSL2	Very high speed Digital Subscriber Line version 2
VoIP	Voice Over Internet Protocol
xDSL	Digital Subscriber Line (either ADSL2plus or VDSL2)
Zring	Impedance modeling the load represented by a worst-case electronic ringer circuit
Ztrip	Impedance modeling of the load represented by electronic ringer circuits, the hook switch, and a single off-hook load
SDTV	Standard Definition TV

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