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Guidelines on DSL power saving modes and non-stationary noise in metallic access networks

Version 1.1.1

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Normative Information

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CONTENTS

1 Scope

Operators in several countries have indicated that there is a risk that some emerging high speed services (e.g. IPTV) could be adversely impacted by the use of the ADSL2/2+ L2 mode as currently standardised by the ITU-T (Recommendation G.992.3 [5] and G.992.5 [6]). Further work is needed to improve the existing L2 mode in international standards and to further quantify the extent of any network harm from inappropriate use of power saving modes. However, if the existing ADSL2/2+ L2 mode is used by a CP care must be taken that parameter values are set to minimise network harm, and the following implementation guidelines should be used until improvements are made to the operational effectiveness of the L2 mode.

This document is intended to inform the reader about the issues surrounding DSL power saving modes, and to guide those intending to adopt the use of such modes to implement them in a way that will inflict the minimum damage to the stability of their own and other operators' networks. It is divided into two parts, the first giving information about and discussing the issues themselves, and the second giving specific guidelines on the implementation of DSL power saving modes to avoid the worst issues. The results of experiment undertaken by BT that were used to set the values of the ADSL 2/ADSL2+ power saving parameters to recommend are given in Annex 1.

DSL power saving modes are currently being investigated in a number of international standards bodies and these guideline may be updated as required to take account of the results of these investigations.

2 Discussion

2.1 Controlling crosstalk in the BT and KCOM metallic access network and the Access Network Frequency Plan

The use of various forms of Digital Subscriber Line (DSL) transmission systems in metallic access networks originally built to provide telephony around the world has become widespread. These systems use much wider ranges of frequencies than telephony, and the close proximity of the wire pairs in telephony cables means that to some extent the signals leak from one pair to another causing interference and limiting performance, an effect known as crosstalk. In any given network it is necessary to have a plan about what frequencies can be used for what purpose in order to bound the types and levels of crosstalk that can exist and so create some degree of confidence about the performance that might be expected when DSL systems are deployed. This is particularly important in a network that is being used in an unbundled way, so that many operators are using the same network.

In BT's and KCOM[1]s access network this plan is known as the Access Network Frequency Plan (ANFP) [1] and [2], which is a public document with contents agreed by representatives of the industry and revised from time to time as technology changes dictate. There is also an associated guidelines document [3] that interprets the dry and technical requirements of the ANFP in terms of what kinds of standardised DSL systems can be used in what ways in the network.

There is however an implicit assumption in the ANFP, and by reference the guidelines, and that is that the signals transmitted by systems connected to the access network are reasonably stationary in their spectral statistics, that is that the signals have a largely constant spectrum that does not continually and unexpectedly change. Provided the signals used are stationary, then the crosstalk environment will be stationary, and so the systems can then expect a stationary noise environment. To a large extent DSL systems in existence today do need a stationary noise environment in order to function reliably.

It is this issue of stationarity that these guidelines have been written to address.

[1] KCOM was previously called KCH and previous NICC NICC specifications relating to the KCOM network use the KCH name.

2.2 Outline of the environmental challenges posed by communications systems, and the JRC Code of Conduct.

Generally speaking it might be thought that communications systems have rather low power consumption, a watt-or-two here and there, nothing much to be concerned about. Unfortunately though all the watt-or-twos add up rather alarmingly when entire networks are considered. The BT's access network already hosts of order 10 million broadband connections, and one of the selling points of these connections is that they are "always on", a fact that is increasingly used by customers who tend to have router-modems that are left switched on. 10-million watt-or-twos make 10-20 MW, being used continuously, and that add up to a lot of carbon dioxide being generated. In fact overall it is worse than that because many router modems consume more like ten Watts than one, upping overall power used to the 100 MW range.

To start to address this real environmental threat the European Commission's Joint Research Centre (JRC) Institute For The Environment And Sustainability, Renewable Energies Unit has issued a Code of Conduct on Energy Consumption of Broadband Equipment [4]. This document sets out a schedule of decreasing targets for the power consumption of broadband equipment, both central and domestic, at various points in the future.

The JRC has then asked many European telecommunications companies to sign up to this Code of Conduct, and many have done so.

Although the targets are voluntary and soft at the moment, the communications industry can expect increasing pressure to lower power consumption over time to encourage it to reduce its overall environmental impact.

2.3 ADSL2 and ADSL2+ power saving modes

ADSL2 transmissions systems are standardised by the ITU-T recommendation G992.3 [5]. Section 9.5 of this standard specifies methods of reducing the transmit power of such systems that may be employed when the user data throughput is nil or low. Similarly ADSL2+, standardized in ITU-T recommendation G992.5 [6], inherits the same functionality by reference to G992.3.

In the description of these power saving modes L0 mode refers to the normal (full power operation), while L2 mode refers to the main mode of interest, a power saving mode that stops short of actually turning the transmit signal off altogether. The operation of this L2-mode is illustrated in Figure 1.

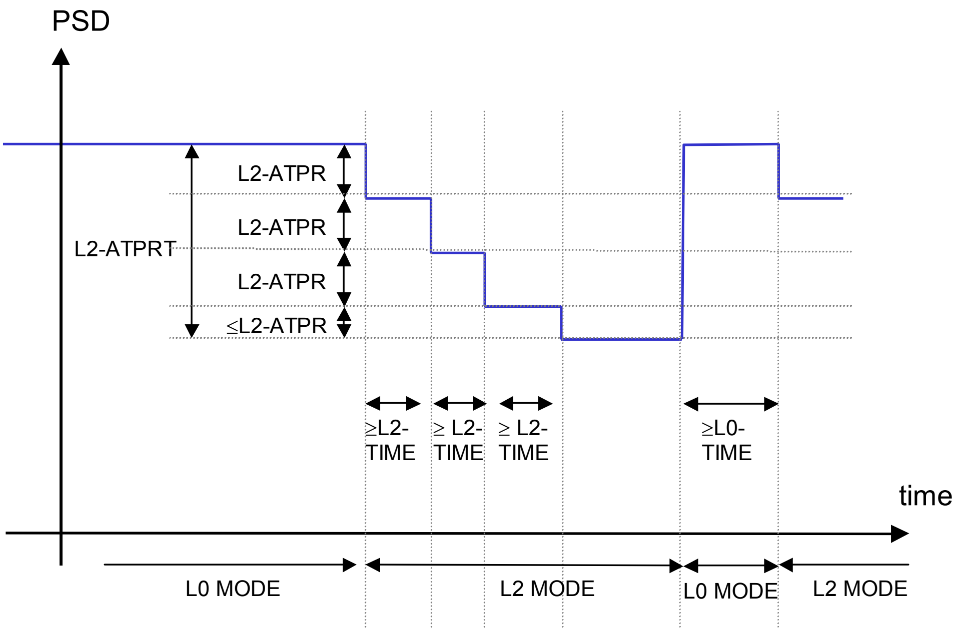

Figure 1 How L2-mode works

In this figure it is assumed that initially the modem is operating in L0 mode and therefore transmitting at full power, when it is detected that little or no user data is being transmitted. As a result entry into L2 mode is enabled, resulting in an initial power reduction by L2-ATPR dB. This level of power reduction must be maintained for a period of at least L2-TIME seconds before further power reduction is permitted. Once this time has passed, if user data requirements still permit, a further reduction in power by L2-ATPR is enabled, and so on, provided that the total power reduction does not exceed L2-ATPRT. If at any time user data throughput demands a higher transmit power level then immediate return to L0 mode is the only option. Once in L0 mode again, this mode must be maintained for at least L0-TIME seconds before L2 mode may be invoked again.

The values of L2-ATPR, L2-TIME, L2-ATPRT and L0-TIME are all under control of the network operator and can be configured through the DSLAM management system. The valid values they may take are defined in ITU-T recommendation G997.1 [7] and reproduced in the table below.

L2 mode parameter	minimum permitted value	maximum permitted value
L2-ATPR (dB)	0	31
L2-TIME (seconds)	0	255
L2-ATPRT (dB)	0	31
L0-TIME (seconds)	0	255

Table 1 Range of permitted values for L2 mode control parameters.

All L2 mode power transitions represent a deviation from stationarity of the transmitted signal. Having said this it is unlikely that the power *reduction* transitions of L2 mode will cause problems for systems operating on other access network pairs. Such transitions can only result in reductions of crosstalk levels being experienced by other systems, and therefore an improvement in their operating signal-to-noise ratios, and it is very unlikely that such improvements will disrupt their operation.

On the other hand the return to L0 mode is not so benign. It will inevitably result in a relative increase in crosstalk levels, and hence a relative decrease in the operating signal-to-noise ratio of systems operating on other pairs, which could very well have detrimental effects either in the form of data transmission errors or, in severe cases, collapse of the transmission system resulting in a retrain. Unfortunately, because of the way the protocol for return to L0 mode has been defined, the increase in transmit power is large and sudden, maximising the potential for adverse effects on neighbouring systems. This is not because the problems of adverse crosstalk have not been considered at all in the design of L2 mode, rather that they have been relegated against the imperative that when the customer needs to transmit data he must not be kept waiting. Despite this it is still possible to use L2 mode control parameters to mitigate the effects; for example smaller values of L2-ATPRT reduce the maximum size of power increase, and larger values of L2-TIME and L0-TIME will decrease the number of such events occurring. This is demonstrated in the results of experiments as described in Annex 1.

The use, existence and definitions of L2 mode are heavily spread through the ADSL2 standard, and their implementation (although not their use) is mandatory in the standard, not optional, even though the standard pre-dates the JRC Code of Conduct. This is because the primary motivation for having the facility was probably heat dissipation management rather than power saving. There is a lot of pressure on the industry to pack many ports into as small a space as possible, and when this is done thermal management and cooling becomes an important issue.

Even though these power saving modes may not originally have been intended to address environmental issues and the JRC Code of Conduct, they remain a possible option for that purpose, and so there is even more motivation to enable these modes of working.

It is worth pointing out that the use of L2 modes does not conflict with the requirements of the ANFP, since all that is happening is that power is being reduced below the maximum permitted. Since the ANFP only invokes a cap on the maximum powers that may be transmitted, there is no conflict with it.

2.4 International Standards Activity

It is not just in the UK that there is operator concern over power saving modes and fluctuating crosstalk. Recent joint multi-operator contributions [10], [11], to standards debates are addressing the issues on two fronts:

a) Asking for the development of new, more benign, power saving modes that preferably do not create fluctuating crosstalk in the first place, or at least create less of it.
b) Asking for changes to standards to improve the robustness of DSL systems that face fluctuating crosstalk.

Both of these fronts have available routes of progress.

On the power saving issue it should be possible to develop DSL transmission systems in which the power consumption of the DSP elements scales with traffic throughput, and this is potentially a much richer source of power saving than attempts to lower the output signal level. This is increasingly true as for example some VDSL technologies have a line signal in the 10mW region, but DSP power consumption in the 1W region.

On the robustness issue DSL systems can be encouraged to become more aware of their noise environment and its fluctuations, so that they can adaptively anticipate noise and change their transmission characteristics to be ready for it.

These initiatives are not just activities in the ITU, but are also supported in ETSI and the USA's ATIS standards body that this year established the NIPP Energy Reporting Metrics (ERM) Committee.

3 Recommended guidelines

3.1 Recommendations for use of ADSL2 and ADSL2+ L2 power saving mode

If L2 power saving mode is used in the BT or KCOM access network it is recommended that the control parameters for it are set according to Table 2.

L2 mode parameter	recommended value
L2-ATPR (dB)	1
L2-TIME (seconds)	≥127
L2-ATPRT (dB)	≤10
L0-TIME (seconds)	≥127

Table 2 Recommended values for L2 mode control parameters.

The meanings of these parameters are explained in [7] and summarised in section 2.3 above. As indicated in Annex 1, application of these recommended values could still result in a power saving of the order 75% of that achievable using the most aggressive power saving parameters but with a reduced impact on DSL performance.

3.2 Recommendations for other forms of power-saving modes

The study of the L2 power saving mode for ADSL2 and ADSL2+ described in section Annex 1 shows that where power saving is achieved by reducing the transmit signal level of a DSL system, then the following recommendations generally hold:

a) That the maximum amount of signal reduction should be limited, preferably to no more than 10 dB, to limit the depth of crosstalk power fluctuation caused.
b) That any time-constants associated with the power reduction should be made lengthy (preferably many minutes) to reduce the frequency of crosstalk fluctuations caused.

In particular these guidelines suggest that the ADSL2/ADSL2+ power saving mode known as L3, which involves switching off the DSL line signal altogether, should be avoided as being far too disruptive to network stability.

The guidelines can similarly be used to inform the implementation of other power saving methods, even those coming into existence before this guideline document can be updated to consider them specifically.

4 References

[1] NICC Document, “Specification of the Access Network Frequency Plan applicable to transmission systems connected to the BT Access Network, Issue 3”, ND1602:2005/08, August 2005, http://www.nicc.org.uk/nicc-public/Public/interconnectstandards/dsltg_spec/nd1602_2005_08.pdf.

[2] NICC Document, “Specification of the Access Network Frequency Plan applicable to transmission systems connected to the KCH Access Network, Issue 2”, ND1604:2006/09, September 2006, http://www.nicc.org.uk/nicc-public/Public/interconnectstandards/dsltg_spec/nd1604_006_09_2.pdf

[3] NICC Document, “Guidelines on the Use of DSL Transmission Systems in the BT Access Network”, ND1405:2005/08, August 2005, http://www.nicc.org.uk/nicc-public/Public/interconnectstandards/dsltg_spec/nd1405_2005_08.pdf.

[4] European Commission Directorate-General Joint Research Centre Institute For The Environment And Sustainability Renewable Energies Unit, “Code of Conduct for Broadband Equipment. - Version 2”, 17 July 2007, http://re.jrc.cec.eu.int/energyefficiency/pdf/CoC%20Broadband%20Equipment%20Final%20version%202%20-%20July%2017.pdf.

[5] ITU-T recommendation G992.3, “Asymmetric digital subscriber line transceivers 2 (ADSL2)”, (01/2005).

[6] ITU-T recommendation G992.5, “Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)”, (01/2005).

[7] ITU-T recommendation G997.1, “Physical layer management for digital subscriber line (DSL) transceivers”, (06/2006).

[8] ITU-T contribution SG15Q4: COM 15 – C 477 – E, BT, “ADSL2plus Performance Impact Experiments with L2 Mode Fluctuating Crosstalk”, May 2007.

[9] NIPP-NAI-2007-165, BT, “ADSL2plus Performance Impact Experiments with L2 Mode Fluctuating Crosstalk”, Nov 2007.

[10] ITU-T Question: 4/15 Temporary Document RJ-020, AT&T, Belgacom, BT, Deutsche Telekom, France Telecom, KPN, NTT, Swisscom, Telecom Italia, Telenor, TeliaSonera, “G.vdsl, G.adsl: Operators requirements on power savings”, Redbank, USA, 08-12 October 2007.

[11] ITU-T Question: 4/15 Temporary Document RJ-023-R1, AT&T, BT, Deutsche Telekom, France Telecom, NTT, Swisscom, Telenor, Telia Sonera, Telecom Italia, “G.vdsl, G.adsl: Network Operators’ General requirements for power savings.”, Redbank, USA, 08-12 October 2007.

Annex 1

Summary of BT experiments with L2 power save mode

BT has carried some laboratory experiments to investigate the likely impact of the use of L2 power saving mode on other systems in the access network. The results of this work have been published as standards contributions to the ITU [8] and to the NIPP/NAI [9].

The form of the experiments is outlined in Figure 2 below. A real DSLAM offers conventional L0-mode service to a real CPE modem over a simulated loop. At the same time a computer-controlled arbitrary waveform generator (AWG) is used to inject noise into the circuit that simulates the kind of non-stationary crosstalk that would be expected if there were several other systems in an access cable operating in L2 mode.

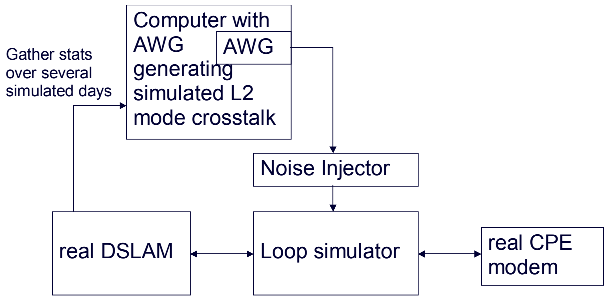

Figure 2 Equipment configuration for L2 mode experiments

The experiment is allowed to continue for an extended period, during which the computer models the normal daily variation in data usage that influences the crosstalk levels generated by each of the simulated L2 mode disturbers. During this extended period the computer also captures the performance statistics (rate, errors, retrains etc) of the real L0-mode connection that is being exposed to the simulated fluctuating L2-mode crosstalk.

The nature of the L2 mode being used by the simulated interferers can be changed by adjusting corresponding parameters in the noise generation part of the computer's program. The experiments were conducted 4 times with the 4 sets of L2 mode parameters given inTable 3

L2 experiment name	Corresponding L2 parameter values
"None"	L2 mode disabled
"B"	L0TIME=127, L2TIME=127, L2ATPR=1, L2ATPRT=10
"A"	L0TIME=16, L2TIME=16, L2ATPR=10, L2ATPRT=20
"Max"	L0TIME=1, L2TIME=1, L2ATPR=30, L2ATPRT=30

Table 3 L2 mode parameter sets used in the BT experiments

The first experiment is the control in which L2 mode is disabled, and the simulated crosstalk is that due to the same number of L0 mode disturbers. Note that the experiment simulates the interfering users switching their modems on and off twice a day, so there is still a degree of non-stationary noise, even in this experiment. Subsequently the experiments were repeated with increasingly aggressive L2 mode parameters sets. Mode "B" has long 127s holding times, small 1 dB power steps and a maximum power cut of 10 dB. Mode "A" has 16s holding times, 10 dB power steps and a 20 dB maximum power cut, while the extreme "Max" mode has 1s holding times, and 30 dB power steps and maximum power cut.

Each of the experiments was repeated at 4 different loop lengths and all the results are summarised in Table 4

It is quite clear from this table that under a wide range of conditions the performance of the victim system is adversely affected by having L2 mode neighbours, and also that the more aggressive the

L2-mode parameters used, the more adverse the effect. The most significant numbers are highlighted in red. For more detailed information about this experiment refer to [8] or [9].

From a power saving point of view it is interesting to note that mild L2 mode settings can offer the vast majority of the benefit of even the most aggressive settings. This is partly because there are diminishing returns from high degrees of power cutback since the power overheads of having the line driver active, even at a reduced supply voltage, quickly dominate. In addition typical usage statistics have very long periods of complete inactivity (e.g. overnight), so that having long L2 mode time constants typically doesn't affect the total power saving significantly.

Loop loss	L2 mode	Avg Bit Rate up	Avg Bit Rate dn	Avg Noise Margin up	Avg Noise Margin dn	total ES up	total ES dn	total Retrains
25dB	Non	1093	9692	6.8	8.3	12	290	10
25dB	B	1108	10669	6.3	7.3	14	409	10
25dB	A	1090	9695	6.8	11.2	15	172	7
25dB	Max	1112	12630	7.0	12.0	18	519	21
35dB	Non	1081	5667	6.4	8.6	17	339	12
35dB	B	1083	5738	6.3	8.6	13	274	11
35dB	A	1061	7235	6.4	7.0	15	546	11
35dB	Max	1059	8969	6.8	9.4	8	951	55
45dB	Non	1041	3987	5.9	8.2	48	273	7
45dB	B	1041	4028	5.9	8.2	18	276	6
45dB	A	1053	4978	5.6	6.5	28	520	6
45dB	Max	1046	6088	5.5	7.0	7	2023	11
55dB	Non	809	3051	6.5	7.2	48	353	10
55dB	B	874	2854	5.9	7.8	13	958	13
55dB	A	895	3595	4.5	5.8	60	1022	12
55dB	Max	834	3825	5.8	6.3	14	2401	7

Table 4 Results of the L2 mode experiments

It is also important to consider the amount of power saving that could be effected by the power saving modes, with the various options set. Table 5 shows the average transmit power for a user doing 1 hour of web browsing in the morning and a 4 hour burst in the evening. It takes into account the power cost of generating this signal level (inefficiency in the line driver etc).

L2 Mode	Average Power need to create line signal/(mW)
Max	77
A	136
B	163
Non	500

Table 5 Transmit power saving estimates

So essentially the table is saying that the maximum line signal power saving is of the order 420mW if the mode is used very aggressively but this mode has greatest impact on DSL performance.

The presentation recommended the use of very conservative parameters, along the lines described in "B". Here the power saving falls to 330mW. So it is likely that most of the power saving benefit of this mode is achieved, even if it is used conservatively.

The power saving may seem small, but it would represent 330kW continuously for 1 million lines, or 2.9GWhr/year, and probably more by the time PSU efficiency and cooling overheads are included.

- End -