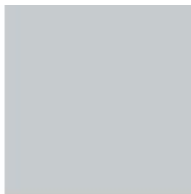


Increasing ADSL Line Rate Speeds in the New Zealand Network

Copper Network Impairments

Version 5.0

24th July 2006



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Table of Contents

1	Foreword	5
2	Executive Summary	6
3	The Affects of Increasing Line Rate	8
3.1	Post Upgrade Line Rate Performance	10
3.2	Extrapolation of Line Rate Performance (Noise Margin).....	10
3.3	Post Upgrade Affects on G.SHDSL and HDB3	13
4	Increasing ADSL Line Rates	14
4.1	Impairments to DSL Performance	15
4.2	Interactions with existing services	16
4.3	Modem Performance.....	19
4.4	Home Wiring and Splitters.....	20
5	Glossary	21
6	References	22

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1 Foreword

Alcatel supplies Telecom New Zealand with contracted Network Engineering and Network Operations services under a Partnership first established in 2002. Alcatel has prepared this document at the request of Telecom New Zealand to help clarify the performance impact of introducing unconstrained line rates on the copper loop.

Telecom recently introduced new Wholesale and Retail broadband plans with 2Mbps and 3.5Mbps ADSL downstream service rates. These plans provided higher service rates than most customers had previously received and have successfully benefited a substantial proportion of the internet customer base. However, there is a percentage of customers who could not achieve their new service rates and some who even experienced a decrease in service rate.

These internet broadband plans are sold to consumers on a best effort basis and share network connections across many users. The data throughput based on line speed is therefore, not expected to be sustained over long periods.

Telecom also has a number of business services in operation, which are sold on a specified service rate basis. These services share the same copper binder as broadband internet services and are therefore susceptible to interference.

With these points in mind, Alcatel has attempted to quantify the most likely affects of the introduction of unconstrained line rates on both:

- ▼ Specified service rate business services, and
- ▼ Best effort broadband internet services.

Any impacts on these services which are caused by factors outside of the copper loop are not considered in this analysis.

2 Executive Summary

This document has been prepared by Alcatel New Zealand at the request of Telecom New Zealand. Telecom has requested that Alcatel quantify, where possible, the impact of the introduction of unconstrained ADSL line rates on services which share the national Copper Access Network. The Copper Access Network carries a number of services that includes broadband internet services and business data services. Internet services are predominantly delivered using ADSL technology while business services use a combination of ADSL, HDB3, HDSL and G.SHDSL technologies.

Based upon extrapolated measurements from the recent 2/3.5Mbps service upgrades and available global evidence, a conclusion has been reached that the introduction of unconstrained ADSL line rates will unavoidably affect the performance of some DSL services. Specifically, DSL services configured on medium (2km to less than 3.5km) to long (>3.5km) copper access binders, and some business services in the same copper access binders. This impact is also expected to increase as ADSL service density increases within the same copper binder.

DSL services interfere with one another and other services that share the same copper binder. A fundamental design principle for the deployment of the technology is to maintain adequate noise margin for a service. With the increasing speeds, there is typically a decline in the available noise margin, due to the increased frequency spectrum and power levels in use. This is characterised by an increase in the line instability and a reduction in service speeds for rate adaptive services such as broadband internet services. A customer would therefore experience lower throughput.

Evidence of this impact can be seen in the recent national speed upgrade of Telecom Wholesale and Retail broadband plans to 2Mbps and 3.5Mbps. There were 383,000 broadband services monitored during the migration to the new plans. Of this number of services nearly 23% or 87,000 services could not achieve the new plan rates. In addition, 7% of customers (16,118 of 235,027) on ASAM, which can be extrapolated to around 5% of all customers, experienced a reduction in performance to below what they received prior to the upgrade.

If unconstrained line rates are implemented nationally, under the current network conditions, there will be a wider service impact. Extrapolating the reduction in available noise margin from the higher speeds, about 170,000 services (46%) are unlikely to achieve even the current rates of 2Mbps and 3.5Mbps.

Business services such as OneOffice and Frame Relay transported over G.SHDSL are also delivered over the same copper binder. While there is insufficient data to be conclusive, it appears that HDB3 services will cross-impact DSL services and limit the speed achievable. G.SHDSL services can also affect ADSL services within the same copper binder, by reducing downstream performance. The impact that ADSL services may have on HDB3 services in the Telecom network is unknown. Further investigation is required to understand the nature of these cross-impacts within Telecom's copper loop network and the affects on business services.

Broadband service performance is influenced by a number of factors, which can each be addressed to improve the quality of service and manage the cross-impact between service types. These factors can be summarised:

- ▼ **Copper loop performance and characteristics:** Copper cable performance affects the minimum performance level of DSL services. Strategies may be required for dealing with:
 - Copper loop length
 - Mixed gauge loops
 - Insulation failure

- Loading coils
 - Faults (e.g. imbalances about earth and miss-connections)
 - Pair-gain impact (analogue and digital), and
 - Crosstalk-control (breaking down larger pair cables into smaller cables or optical fibre overlays).
- ▼ **Customer premises wiring:** Home or business wiring can have a significant impact on DSL performance, and wiring methods and terminations need to be suitable for DSL. A move to centralised splitters would for example help to alleviate some of the performance issues associated with home wiring performance.
- ▼ **Modem behaviour:** Ensure that modems behave predictably, and meet minimum rate and reach performance expectations. Parameters for predictable behaviour include:
- Modem power back-off behaviour
 - Modem behaviour under the influence of noise disturbances (i.e. the error correction capability of the modem)
 - Modem margin estimation capability (i.e. all modems should use the same definition of margin), and
 - Modem ability to control output power based on DSLAM control.
- ▼ **External noise sources e.g. Power Line, Appliances, Microwave:** Plant performance verifications may be necessary to understand the noise environment within the copper loop. For example, issues tend to appear when aerial plant is located in close vicinity to AM broadcast stations or power line interference sources.
- ▼ **The concentration of ADSL services on a per-cable basis:** Control the maximum number of DSL services deployed in a copper cable to reduce and control crosstalk affects, and the potential flow-on affects to business services. This would require strategies to deal with forecast growth for broadband internet services and protection mechanisms for business services.
- ▼ **The concentration of other copper loop services in the same cable with ADSL services e.g. E1-HDB3, SDSL, HDSL:** Further work will be required to understand the cross-interactions with ADSL and services delivered using other technologies that share the same cable. Strategies would be required to deal with problem cables where these services are having severe impacts on business DSL services and/or on themselves.

These factors need to be addressed by the CPE industry, a Telecom Operator or a Property Owner.

These factors can be covered by an industry Copper Spectrum Management Plan and it is recommended that such a plan be established in New Zealand.

3 The Affects of Increasing Line Rate

Prior to April 2006, Telecom’s retail ADSL plans were primarily (upstream / downstream):

- ▼ 128Kbps / 256Kbps
- ▼ 128Kbps / 512Kbps
- ▼ 128Kbps / 1Mbps, and
- ▼ 128Kbps / 2Mbps.

During April 2006, Telecom launched a project to upgrade retail ADSL plans to one of the following:

- ▼ 128Kbps / 2Mbps
- ▼ 128Kbps / 3.5Mbps, and
- ▼ 512Kbps / 3.5Mbps.

The increase in downstream rate required implementing a change to the line rates at which the DSL exchange would signal the DSL modem.

Effective plan (data) rate	128Kbps	256Kbps	512Kbps	2Mbps	3.5Mbps
Line Rate	160Kbps	320Kbps	608Kbps	2.56Mbps	4.288 Mbps

The introduction of the new line rates caused a number of cross-service and inter-service affects.

These affects were:

- ▼ A reduction in the noise margin
- ▼ Failure to reach planned line rate, and
- ▼ Reduced stability.

The noise margin of a service provides a relative measure of how reliably data can be transmitted. The greater the noise margin, the more robust the service will be. For example, an error could be injected by a large circuit breaker switching, lightening or another modem retraining. If the noise margin is insufficient, there will be an impact on service performance.

Post synchronisation, if the DSL modem detects that the noise margin has fallen below a 0dB threshold, it will cause a resynchronisation and a probable reduction in the downstream/upstream rates. (0dB ⇒ BER<10⁻⁷)

An unstable line will have more data errors, and the modem may retrain more frequently, which causes more noise in the cable. Interleaving may reduce the impact of errors.

All of these affects are due to the following:

- ▼ Copper loop performance and characteristics
- ▼ Customer premises wiring
- ▼ Modem behaviour
- ▼ External noise sources
- ▼ The concentration of ADSL services within a cable binder, and
- ▼ The concentration of other copper loop services within the same cable binder as ADSL services.

3.1 Post Upgrade Line Rate Performance

After the upgrade, 77% of customers achieved their assigned line rates.

Table 1 gives the number of ADSL connections that could not achieve the new line rates after the upgrade:

Planned bitrate DS	Planned bitrate US	Below Target Port Count	ADSL	Plan count	% Failing to meet target
160	160	0	0	2119	0.00%
256	256	1	1	93	1.08%
256	259	0	0	95	0.00%
256	259	0	0	95	0.00%
284	384	0	0	2	0.00%
320	160	927	927	56022	1.65%
320	320	0	0	2754	0.00%
608	608	1	1	1323	0.08%
1280	160	35	35	2104	1.66%
1536	160	134	134	3860	3.47%
1536	320	0	0	9	0.00%
1856	608	0	0	71	0.00%
1865	608	0	0	1	0.00%
2560	160	31097	31097	190779	16.30%
4288	160	21998	21998	75344	29.20%
4288	608	1915	1915	9168	20.89%
8000	320	16444	16444	19163	85.81%
8000	800	14306	14306	20092	71.20%
0	0	0		6	
		Below ccts		Total ccts	Target fail %
		86858		383100	22.7%

As at: 9/6/06

Table 1: ADSL (Alcatel, Conklin, Nokia) Line Rates post 2Mbps/3.5Mbps plan upgrades

As shown in Table 1, 86,858 customers (22.7%) do not achieve the provisioned data rates.

Alcatel notes that lines with 8,000 in the first column of Table 1 are unconstrained business plans that have now been withdrawn from sale by Telecom.

Approximately 7% customers (16,118 of 235,027) on ASAM experienced a reduction in performance to below what they received prior to the upgrade. Customers with higher line rates were more likely to suffer degradation.

3.2 Extrapolation of Line Rate Performance (Noise Margin)

Over time, it is certain that the performance (line rate) of the 22.7% of services quantified in the table above will deteriorate. These services are already at their performance limit. Due to the introduction of unconstrained line rates and increased service penetration, cable binder noise will rise, reducing the performance of these lines even further. 22.7% is the lower bound of the number of services that will deteriorate because of line rate increases.

What is difficult to quantify is the number of services currently achieving the planned line rates that will deteriorate below this, because of the introduction of unconstrained line rates.

Before the introduction of 2Mbps and 3.5 Mbps plans, 55% of services had a maximum possible downstream noise margin of 28-33dB. While noise margin is not the only parameter that is indicative of service performance, it is valuable in that it is directly related to service performance and is easy to understand.

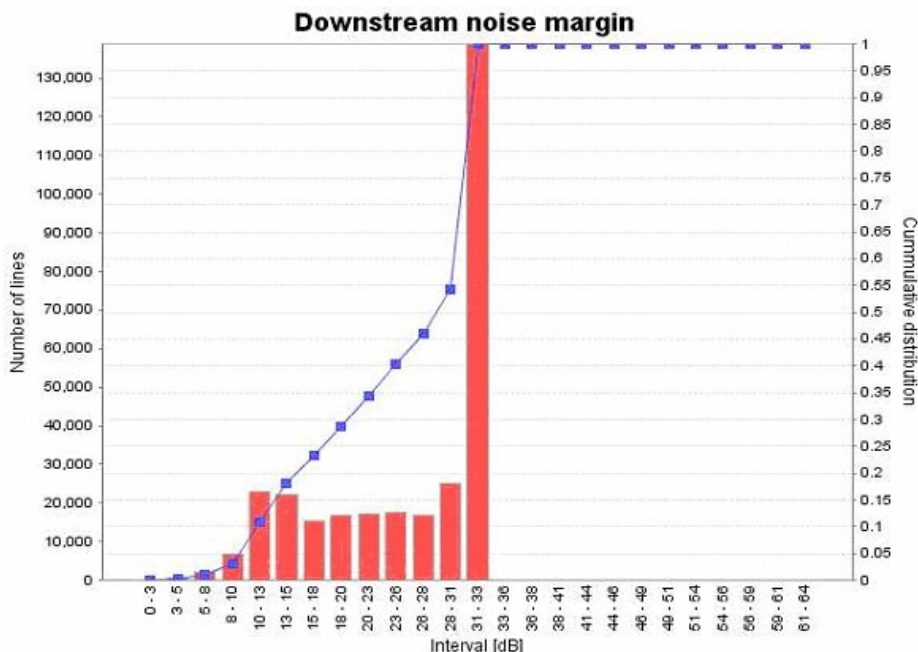


Figure 1: Noise Margin Analysis prior to the upgrade

After the introduction of 2Mbps and 3.5Mbps services, less than 30% of services still had the maximum possible downstream noise margin.

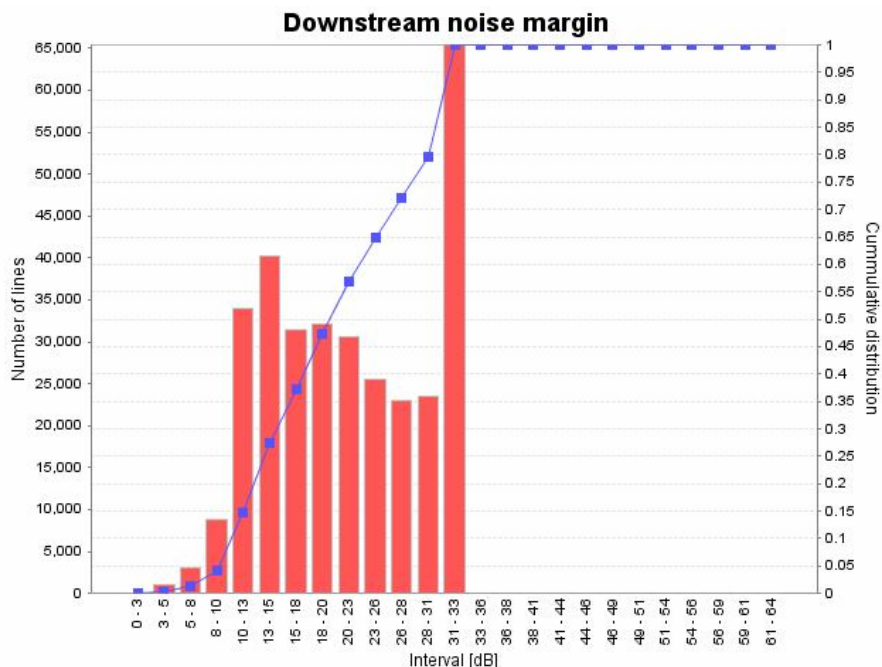


Figure 2: Noise Margin Analysis post upgrade

As line rates and service penetration increases, downstream noise margins will fall. Once the noise margin drops below the specified threshold 0dB (error rate limit), modems typically respond by re-synchronising and probably reducing their line rates.

With the following assumptions, an indication of the impacts on best effort services can be determined:

- ▼ Assumption 1: The upstream rate, both before and after the upgrade, is not required to be considered in this discussion.
- ▼ Assumption 2: Downstream Noise Margin in the 8 to 15dB (12 \approx ±3dB) range correlates with services at highest risk of being unable to achieve planned downstream rates. 12dB is the target noise margin the modem must achieve in the downstream direction to sync at the provisioned line rate initially.
- ▼ Assumption 3: Degradation extrapolated from measurements on 235,027 ASAM services is applicable to the entire service population of 383,100 of ADSL services.
- ▼ Assumption 4: The increase to unconstrained line rates will degrade the achievable downstream rates for a number of services that are achieving the target today. The assumption is that the change to unconstrained line rates will cause proportional impact as increasing downstream bitrates to 2Mbps and 3.5Mbps had.

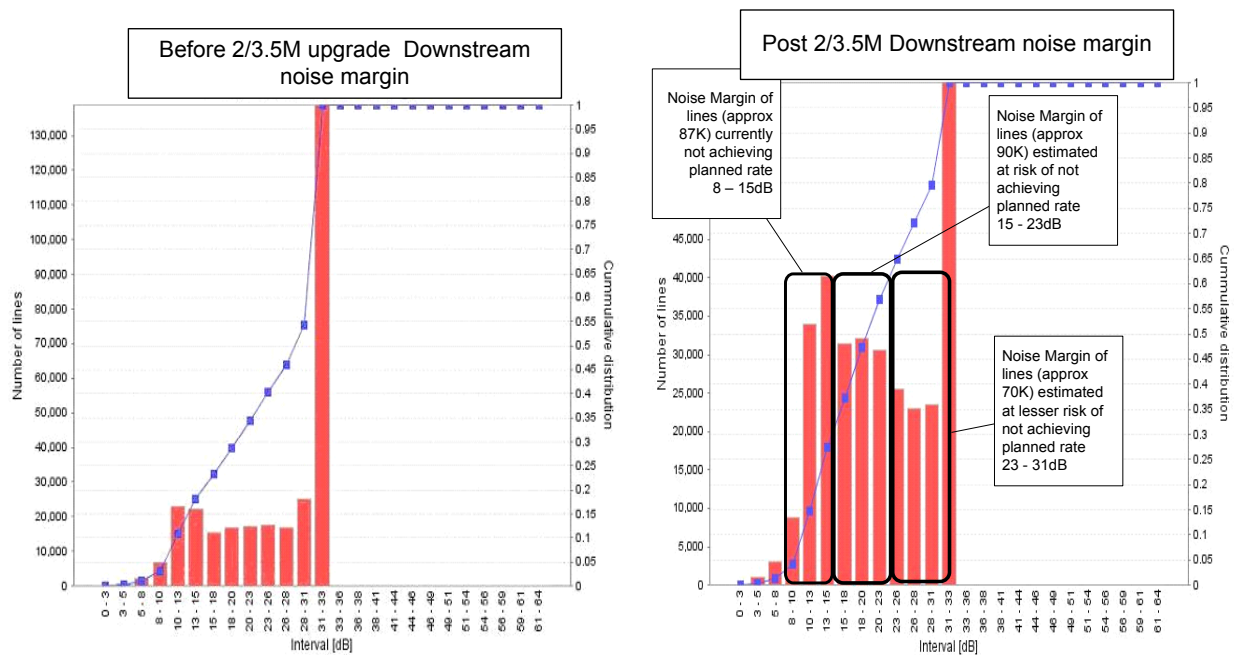


Figure 3: Banded impact post upgrade

The second graph above represents the noise margins of all ASAM ADSL services after the downstream rate increases. The left hand black box encloses approximately 87,000 lines which are assumed to be the 87,000 services that do not achieve plan rates today. Noise margin measurements are dynamic and will change over time. Thus a particular ADSL service may have dropped tones and/or QAM orders to achieve the 12dB noise margin (or required bit error rate) resulting in a lower line rate speed than that provisioned. Thus some services not achieving plan, at the time of measurement, may show better than 12dB noise margins; where the modem has already dropped tones and/or QAM orders. The modem will only attempt to “reuse” available tones and/or QAM orders during a resynchronisation that is yet to occur. The

exact modem behaviour under dynamic noise environment is dependent upon the manufacturer.

Of the entire service population, it is projected that an increase to unconstrained line rates would place 90,000 lines that currently have downstream noise margins in the range of 15-23dB, at a risk of service degradation. A further 70,000 lines with current downstream noise margins in the range of 23-31dB may also be at risk.

Extrapolated impact on population of 383,100 Services			
	Noise margin today	No. of lines	Cumulative
Expected degradation below current plan rate	8-15dB	87,000	22.7%
Possible degradation below current plan rate	15-23dB	90,000	46.2%
Less likely degradation below current plan rate	23-31dB	70,000	64.5%

It is undesirable from a stability perspective to allow modems to train up to an unconstrained line rate, regardless of the situation in the cable. If the noise environment changes, it is unlikely that the modem will be able to maintain this rate and will therefore, cause unwanted crosstalk while attempting to retrain to the unconstrained rate.

Each time a modem is retrained (for example, when a customer that is unable to reach the target rate resets their modem to try once again,) the training process can cross-impact other customers in the same cable.

A possible cause of instability on these lines (especially in CBD areas) is the use of "unfriendly" modulation techniques such as Frame Relay over E1 (HDB3), but further investigation is required to determine this impact.

3.3 Post Upgrade Affects on G.SHDSL and HDB3

New symmetric business grade services are typically configured on G.SHDSL with specified up and downstream rates. The risk for these services is that since the modem cannot reduce the line rate to maintain the noise margin, noise margins will reduce. Noise margins below target will increase the service error rate and may cause the service to fail.

More analysis is required to quantify the affects of the 2Mbps and 3.5Mbps rate increases on symmetric business services, so that an extrapolation can be made for when unconstrained line rates are introduced.

At this stage, there are no measurements available which show the impacts on HDB3 (E1) services from the 2Mbps and 3.5Mbps rate increases. If any impact is encountered because of unconstrained line rates, it is most likely to be on the group of services with the longest (up to 2 Km), unrepeated signal paths.

Further work is required to study in detail the impacts on G.SHDSL services due to ADSL and legacy transmission systems such as E1, B-ISDN and SHDSL etc.

4 Increasing ADSL Line Rates

With further ADSL line rate increases in the down and/or upstream directions, a number of technical and performance issues can be expected in the copper access network. Many of these are the same as originally identified for the 2Mbps and 3.5Mbps upgrades. Areas impacted may be as follows:

- ▼ G.SHDSL and business ADSL services – increase in the number of customers with unstable and/or risky circuits.
- ▼ Symmetric Digital Subscriber Line (SDSL) performance or High bit rate Digital Subscriber Line (HDSL) systems that carry E1 voice or data traffic.
- ▼ Other copper loop systems that are operating with marginal performance today: Corollary is that other existing copper loop services cause performance impairments on ADSL such that internet plans are unstable or are not attainable.
- ▼ Customers closer to DSLAMs will generally see a performance improvement. Customers at increasing distances from the DSLAM are likely to see an average reduction in line speed.
- ▼ Some brands of modems may perform poorly when positioned near the exchange (<1.5km) in that they do not train to the expected line rate: This could be an issue with the modem firmware and ADSL engines.
- ▼ Reduction in the maximum reach of broadband internet services: Customers closer to the DSLAM will generally receive a better service at the expense of customers at the end of long loops who will suffer service degradation (or receive no service). This will depend on the following:
 - State of the copper cable
 - Modem capability
 - Customer premises wiring performance, and
 - External noise sources.
- ▼ The attainable line rates will vary between different parts of the copper network due to variations in copper plant, customer premises wiring and variable modem performance. Some areas that are located near sources of radio interference (e.g. AM Radio Stations) may exhibit poor line performance and suffer from increased instability.
- ▼ Customer premises wiring issues and other copper plant performance issues may be highlighted through the reduced noise margins at the higher speeds.
- ▼ Customer reported faults are likely to become more complicated and time consuming to resolve, as modems tend to take longer to train and performance tends to become more susceptible to line disturbances and noise issues. Comprehensive measures may be required to deal with faults, examples include, centralised splitters to resolve customer-wiring faults and modem swap-outs for better performing modems.

4.1 Impairments to DSL Performance

The theoretical maximum speeds of ADSL1 (approximately 8Mbps) and ADSL2+ (approximately 24Mbps) can only be obtained under the most favourable conditions. Conditions are most favourable with:

- ▼ Very short lines (typically <1km)
- ▼ The cables are in an excellent state of repair
- ▼ Heavier gauge copper has been used in the cables
- ▼ The absence of interference from other DSL services in the same cable
- ▼ The absence of other interference sources, and
- ▼ Excellent modems.

Particularly when ADSL2+ service penetration is very low, interference between ADSL2+ subscribers in the ADSL2+ specific parts of the spectrum will be at their lowest. Excellent ADSL2+ service rates will be possible for a large number of the early subscribers, even those with longer lines. As ADSL2+ service penetration increases, the formerly clean spectrum will degrade with increasing noise and crosstalk, and the service performance for all customers will be degraded. Significant service degradation is to be expected for some customers as community take up becomes common.

Thus, expectations of the maximum achievable performance in the field will be lower and reflects the real-world conditions that exist with today's copper loop networks. This is true for copper networks across the world, ref. 9 and 10.

The speed and stability of DSL on any given line in the access network is a function of the signal to noise ratio at the end of that line, which in turn depends on:

- ▼ Loop length, quality and dimensions of the copper cable
- ▼ Amount of crosstalk, which is directly related to "cable fill" and the proportion of pairs in the cables carrying DSL
- ▼ Noise from sources in the home or premises, including home wiring
- ▼ Noise picked up from the environment e.g. radio frequency interference
- ▼ Faults that might be present on the line, and
- ▼ The quality capability and performance of the customer's modem.

It is important to recognise that transient noise sources such as IBNE (Isolated Burst Noise Events) and REIN (Repetitive Electrical Impulse Noise) are also a threat to DSL performance. One European operator has noted marked increases in reported DSL faults during the Christmas season when many Thyristor controlled rope lights operate daily over several weeks¹.

¹ Report: MUSE D B2.2 – Enhanced DSL Algorithms, 21/12/2005.

The geographic coverage of a given speed depends on:

- ▼ Topology of the access network:
 - Buried/aerial plant
 - Types of cables
 - Types of termination systems, and
 - Conductor insulation and quality.
- ▼ Statistical distribution of line lengths: Short loops (<2km) versus loops lengths exceeding 4.5km, and
- ▼ Presence of multiples or bridged taps: Multiple cable pairs connected off single feeder cables causing line imbalance and line performance disturbances at specific DSL frequencies.

These factors are based on the laws of physics and would be the same for any Operator providing a DSL service within Telecom's copper access network.

It is important to realise that Telecom's present copper loop networks were designed and optimised for voice frequencies (DC – 4KHz). The later arrival of DSL, with its use of frequencies beyond 1MHz, means that many of the copper loop networks operated today are not necessarily optimised for DSL performance and will provide varying levels of performance. Thus, merely increasing the line rate of ADSL services in these networks will not guarantee performance and speed improvements for customers.

Copper loop access networks vary from country to country. For example New Zealand has on average longer loops compared to the UK.

An industry accepted Copper Spectrum Management framework with an associated Access Network Frequency Plan (ANFP)² is preferable to govern the use of Telecom's copper access network. Proper management of spectrum usage and transmission power levels will ensure that the network performance is at its best and that all users are able to make use of the network in the best economic manner, with minimal impact on one another's services.

4.2 Interactions with existing services

By design, ADSL is spectrally friendly to other existing copper-based services such as, B-ISDN, E1 (HDB3) and early generation DSL technologies like SDSL and HDSL.

The HDB3 service technical limits were defined at a time when there were very few other digital services in the network (before the advent of DSL), but this has now changed and should be reflected in an Access Network Frequency Plan (ANFP). HDB3 services currently operating at their technical limits will be impacted with increased ADSL line rates and further ADSL penetration.

When ADSL is located in the same cable binder with other technologies, such as E1 and B ISDN, the electromagnetic coupling that exists between the different cable pairs, crosstalk, will generally affect the performance of the ADSL service, before affecting the performance of older legacy copper-based transmission systems, ref 7.

² An access network frequency plan (ANFP) is a spectrum management plan for controlling interference, caused by crosstalk, within a metallic access network. The existence of an ANFP therefore allows operators to deploy services in a predictable and reliable manner: ND1602:2005/08 Specification of the Access Network Frequency Plan applicable to transmission systems connected to the BT Access Network.

However, there are exceptions where other non-DSL services that are already operating at their technical limits, may be impacted by the increased noise floor created by adjacent ADSL services. With the addition of unconstrained ADSL line rates and the resulting increase in the cable's noise floor, the already compromised service might conceivably suffer service degradation, which will typically range from increased bit error rates through to outright service failure, depending on the penetration and power levels of the other ADSL services. With the addition of unconstrained ADSL line rates and the resulting increase in the cable's noise floor the impact that these ADSL services may have on HDB3 services in the Telecom network is unknown.

There are two approaches available for resolving interferences to other services, either:

- ▼ Accept the impact on these services, or
- ▼ Mitigate the impact where possible, by separating the services on to separate binders.

Separating services, would introduce additional capital or operational expense, because of either laying new cables or rebalancing services across adjacent binders.

Other legacy DSL services such as HDSL and SDSL generally use frequency spectra that are in conflict with ADSL. HDSL systems in the Telecom network employ the 2B+1Q line code, with two-way baseband transmission and consequently, have a relatively wide frequency spectrum. Typically, the single pair HDSL service, HDSL 1p, will affect DSL services in the same cable. Like HDB3, the HDSL service technical limits were defined at a time when there were very few other digital services in the network, but this has now changed and should be reflected in an ANFP.

HDSL services currently operating at their technical limits will be impacted with increased ADSL line rates and further ADSL penetration.

However, the majority of these legacy services, which Telecom still operates in the copper network, will have a far more detrimental impact on ADSL services in the same cable, than the other way around.

Consequently, a number of European operators are looking to exit older legacy HDB3, SDSL and HDSL systems in favour of the more spectrally compatible G.SHDSL, ref 7. However, G.SHDSL 1p (2Mbps) operating in the same cable as ADSL will result in a reduction in the downstream performance of ADSL, this reduction will vary depending on the SHDSL service speed and power levels used in the G.SHDSL copper loops.

Similarly, older 30-channel PCM systems and Primary Rate ISDN, that employ the HDB3 line code with its wide power spectral density, are generally far more of a problem to ADSL performance. A recent study in Norway³ showed that E1 services (1.5km length) in the same cable had a marked degradation on ADSL performance line rates, reducing the achievable ADSL line rates by around 45% at 1.5km. However, at longer loop lengths, 4km and beyond, the performance reduction on ADSL (\approx 1.7Mbps) services, due to the presence of E1 services (1.5km into the cable) was small. At 4.5km and beyond, the physical characteristics of the cable

³ SINTEF STF40-F02024: Plan for the use of frequencies in the Norwegian access network – a proposal.

were far more dominant and the presence of the E1 services was insignificant, with line rates falling below 1Mbps.

4.3 Modem Performance

A large number of different brands of DSL modems are in use on Telecom's copper network. The present Telecom PTC-270 is inadequate for understanding the specific modem behaviour in the network with the introduction of unconstrained line rates. The present PTC test looks at the electrical safety aspects of the modem and brief static operation. These tests are limited and do not consider the dynamic behaviour of the modem.

Of concern is modem behaviour that may cause the modem or DSLAM to transmit excess power, which will affect other customers within the same binder.

Work carried out by British Telecom for MUSE to look at improving the performance of DSL has shown that modem performance is critical in closing the gap on ADSL performance in the network, ref 6. Thus, Telecom and any other operators are likely to find the need to carry out more detailed modem testing to verify correct functioning. Some of the modems already deployed are likely to be non-conformant.

The new testing could consider:

- ▶ Modem rate and reach performance: Under laboratory conditions the modem should meet a minimum line rate and distance performance test.
- ▶ Modem power back-off behaviour: How does the modem retrain to the line and what power levels does it create that may interfere with other services in the same binder?
- ▶ Modem behaviour under the influence of noise disturbances: What is the error correction capability of the modem when interference noise sources are introduced?
- ▶ Modem margin estimation capability: All modems should use the same definition of margin to ensure that:
 - Network stability is maximised (benefit to the network operator)
 - Modems operating in the same line conditions give approximately the same capacity throughput (fairness amongst customers irrespective of modem brand), and
 - Neither the modem nor DSLAM use excess power.
- ▶ Modems ability to control output power based on DSLAM control: How well does the modem control it's transmit power to the line?

Performance testing of new modems may be required to set minimum and consistent modem performance standards for a better service experience for customers:

- ▶ Service is less likely to suffer from disruption to levels of interference present in the copper loop: Modems will require enhanced noise immunity, and
- ▶ Increased service show-time: Based on effective problem identification in the network and reducing the effects of variables such as modem performance.

4.4 Home Wiring and Splitters

When ADSL was first developed it was widely thought that its performance would be primarily limited by crosstalk from neighbouring copper lines and copper line attenuation. However, in work carried out for MUSE by British Telecom ref 6, they have shown that a major threat to DSL performance is external electromagnetic interference in the form of noise that is induced into the copper loop. Their work also showed that not all interference noise sources originate from the copper loop network. In fact customer premises have been proven to make significant contributions of noise and interference to ADSL performance.

Research carried out by Alcatel, ref 8, has shown that centralised splitters are one of the better solutions for problematic in-house wiring. A centralised splitter maximises immunity against electromagnetic interference (noise) that may be present in a domestic environment. The centralised splitter generally improves the balance termination at the customer's premises, helping to reduce the unwanted conversion of common mode to differential mode interference.

Single Ended Line Testing (SELT) is an emerging technology to aid network operators in the pre-provisioning of DSL services. The pre-qualification of a line using SELT techniques is a way to identify the transmission channel (loop length, termination and branches in the access network). However, the technology has limitations and at this stage is unable to identify copper network faults.

For a number of customers with poor quality internal wiring, the only way they will be able to obtain higher ADSL line rates will be to re-wire their premises. However, in the first instance, the use of a centralised splitter to 'isolate' the customers POTS wiring and reduce unwanted noise, may be sufficient to enable the customer to achieve better line rate speeds.

5 Glossary

The following table defines special terms, acronyms and abbreviations used throughout this document.

Acronym / Abbreviation	Definition
ADSL	Asymmetric Digital Subscriber Line
ANFP	Access Network Frequency Plan
ASAM	Advanced Services Access Manager (Alcatel DSLAM)
CPE	Customer Premises Equipment
CSM	Copper Spectrum Management
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
FTTN	Fibre to the Node
HDB3	High Density Bipolar 3 coding
HDSL	High bit rate Digital Subscriber Line
HSI	High Speed Internet
IBNE	Isolated Burst Noise Events
IP	Internet Protocol
ISDN	Integrated Services Digital Network
LLU	Local Loop Unbundling
POTS	Plain Old Telephone Service
REIN	Repetitive Electrical Impulse Noise
SDSL	Symmetric Digital Subscriber Line
SELT	Single Ended Line Testing
SHDSL	Symmetric High speed Digital Subscriber Line
VDSL	Very high bit rate Digital Subscriber Line
VoIP	Voice over IP

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