



**Knossos Networks Limited**

**Draft Determination on Unbundled Bitstream Service  
Technical Aspects of Telecom Submission**

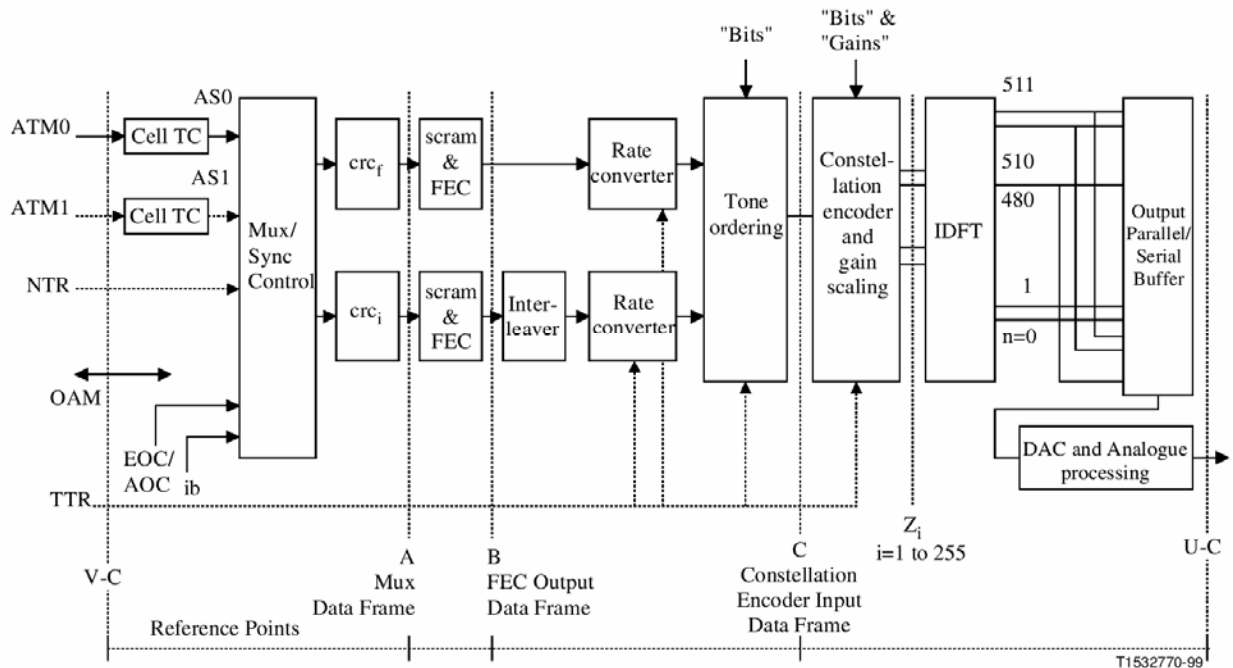
**8 June 2005**

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# Interleaving

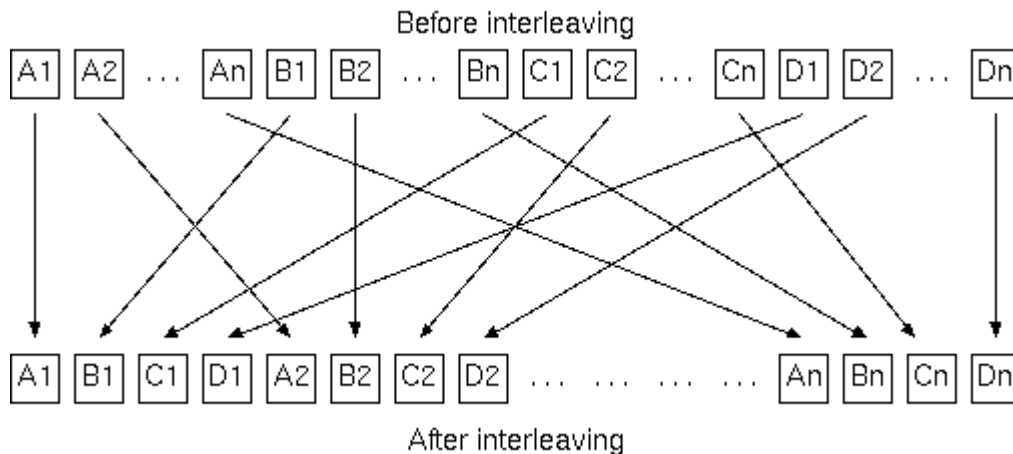
1. Section C2 of the Telecom submission makes several arguments in favour of requiring interleaving to be enabled on UBS lines. To discuss this requires an understanding of how interleaving works, and how it relates to forward error correction (FEC).
2. The following block diagram<sup>1</sup> shows the process of encoding an ADSL signal onto the wire:



3. ADSL relies heavily on the Reed-Solomon FEC codes to correct lost data caused by impulse noise. Impulse noise refers to small bursts of noise, which may cause short-term interference with the signal. ADSL transmission is divided into frames, onto which Reed-Solomon coding is applied to achieve forward error correction. FEC allows for single bytes to be corrected within a frame should one be unreadable due to a noise impulse.
4. Interleaving provides additional opportunities for the FEC to deal with longer noise bursts or higher data rates. By interleaving bytes from several frames, the FEC codes can correct several consecutive byte errors, as might be expected from a short-term noise burst. This achieves a more noise-immune transmission, but at the expense of latency due to the need to accumulate frames into the interleave buffer prior to transmission.
5. Interleaving on a DSLAM translates to an interleave factor, which is a power of two, ie, 2:1, 4:1, 8:1 etc; an interleave factor of 4:1 means that one byte of each of four frames is sent. For example, given four frames A-D, each of n bytes, the following

<sup>1</sup> ITU G.992.1, Asymmetric digital subscriber line (ADSL) transceivers

diagram shows how the transmission order of the bytes in these frames (after the FEC codes are added) is re-arranged after the 4:1 interleave factor is applied:



6. If a noise burst destroyed the two consecutive bytes B2 and C2, these could both be recovered from the FEC codes added prior to the interleaving, whereas without interleaving, two consecutive lost bytes from the same frame would render the frame unrecoverable. With an interleave factor of four, up to four consecutive bytes can be recovered.
7. DSLAMs typically configure interleaving in terms of an interleaving delay and adjust the interleave factor according to the actual speed negotiated when the line is brought up. Thus the interleave factor scales with the actual negotiated bit rate. ADSL transmits multiple bits simultaneously, on multiple sub-carriers; at higher bit rates more sub-carriers are used and more bits are transmitted per sub-carrier, increasing the chances of multiple bytes being wiped out by a single short wide-spectrum noise burst. Scaling the interleave factor with bit rate addresses this problem, and also provides a more “real world” assessment of the latency caused by interleaving.
8. Disabling interleaving on a single line affects the ability of the line to correct errors, especially at high data rates. Uncorrected errors will cause packet loss, and a high number of uncorrected errors may cause the DSLAM to re-distribute power to compensate, or cause the ADSL link to retrain.
9. ADSL has a mechanism known as “bit-swapping” to respond to minor changes in the characteristics of the transmission line. Bit-swap requests operate on individual sub-carriers to either increase or decrease the power on the sub-carrier, or increase or decrease the number of bits transmitted on each sub-carrier. However, power adjustments must be made such that the overall power is not changed. If power is increased in one sub-carrier, it must be reduced in others to compensate. Similarly, changes to the bit-rate per sub-carrier must also be done in concert; the total number of bits transmitted per symbol must not change, as this would alter the overall bit-rate, and require full resynchronisation.
10. Overall power used and bit-rate is determined during the synchronisation phases, where the characteristics of the line are measured by the DSLAM and the modem to determine the appropriate data rate, power level and distribution of power and bit-rates across the available sub-carriers. Power levels are chosen according to power spectral density priority and signal-to-noise ratio parameters defined in the port profile on the DSLAM. This process is performed regardless of previously

experienced error rates.

## **Effect of disabling interleaving**

11. Given all of the above, we have some difficulty with paragraph 151 of the Telecom submission and the subsequent conclusions drawn from this paragraph. The submission firstly claims that some ADSL modems, “when requested to turn interleaving off, also turn off Reed Solomon (sic) coding at the same time.”
12. Reed-Solomon FEC coding is not an optional parameter of ADSL; it is always on. As observed above, turning off interleaving does reduce the effectiveness of FEC coding, especially in the face of short-term wide-spectrum noise bursts at higher bit rates.
13. Secondly, it is claimed that errors may cause resynchronisation to a lower speed. Again, while it is true that errors may cause resynchronisation, this process will negotiate according to current line conditions. Depending on the nature of the changes to the line characteristics since the previous negotiation, the renegotiated speed may be lower or higher than the previously negotiated speed, but this will not be affected by the previously experienced error rate, nor will it be affected by the interleave setting.
14. Thirdly, paragraph 151 claims that a modem may request higher power, when in fact there is no mechanism available to do so; power may be redistributed, but not increased.
15. Therefore, we fail to see how disabling interleaving could adversely affect other lines as claimed in paragraphs 150 through 155, beyond introducing higher error rates at high bit rates on lines configured with interleaving off.
16. Paragraph 171 of the Telecom submission suggests that, as adding an interleaving option would require additional profiles to be defined, Telecom would need to “double the number of profiles it currently has”. It is true that if the UBS profiles have two profiles for each configuration, one with interleaving on and one with interleaving off, there would be twice as many UBS profiles.
17. Telecom has informed us<sup>2</sup> that there are approximately 20 profiles in use. The older Nokia DSLAMs can support approximately 50 profiles, and the Alcatel ASAM supports “hundreds”. The Conklin mini-DSLAMs support approximately 15 profiles, but the profiles configured do not include many of the CBR-type services that are configured on the exchange-based DSLAMs.
18. For the exchange based DSLAMs, we do not believe that the additional profiles required to support non-interleaved or low-latency services represents a barrier to this service being provided.
19. Allowances may need to be made for mini-DSLAMs. However one would note that such DSLAMs would have poorer latency characteristics due to the restricted nature of the upstream trunks, so users on such DSLAMs would not gain as much benefit from a low-latency option as they might on lines attached to exchange-based DSLAMs.

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<sup>2</sup> Meeting between Don Stokes and Dr Murray Milner, 7 June 2005

## Recommendations as to interleaving

20. We believe that interleaving is purely a quality of service issue for the Access Seeker, not for Telecom. It does not affect other users and providers. Therefore, we recommend that a non-interleaved option should be available.
21. However, we would also like to point out an alternative. Telecom currently sets the interleaving delay on all its ADSL services to 16 milliseconds.<sup>3</sup> A lower interleaving delay could achieve much of what is being requested; indeed a large ADSL provider we spoke to operates all its services with an interleaving delay of four milliseconds. This represents a difference of 24 ms of round-trip latency.
22. Furthermore, we believe that the primary users of a non-interleaved or low-latency service would be less interested in high downstream bit rates. If the number of available profiles is the major issue in deploying a low-latency service, this could be done for lower-bandwidth options, while leaving interleaving unchanged for higher-speed services.

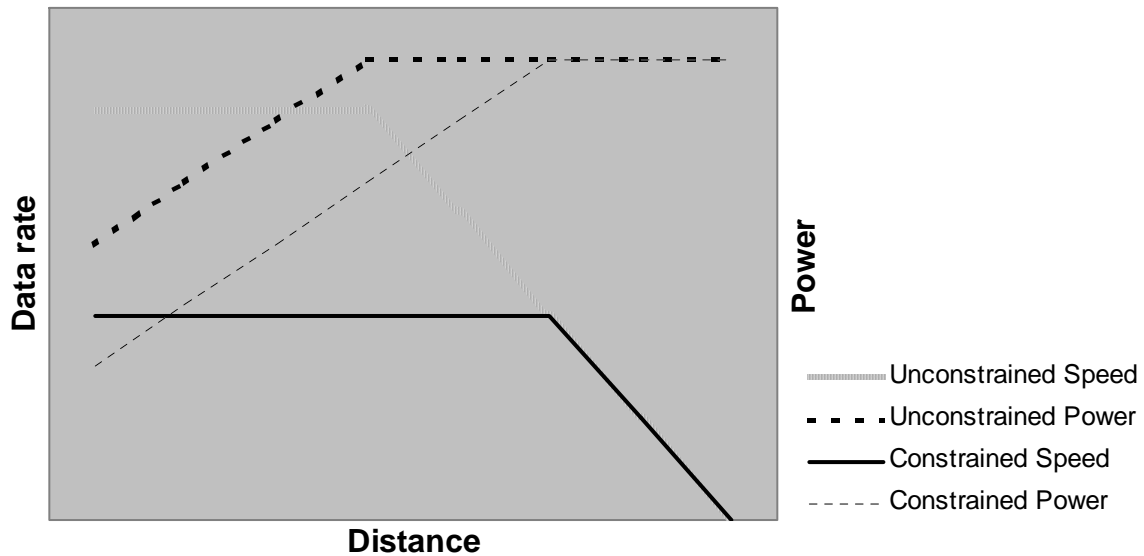
## Unconstrained Downstream Speed

23. Telecom's submission suggests that downstream UBS services should be copper rate limited in steps of 256 kbps, 1 Mbps, 2 Mbps and 3 Mbps instead of a single, unconstrained downstream speed option as recommended by the Draft Determination. The following discusses the effects of unconstrained ADSL services.
24. ADSL connections negotiate overall power during the synchronisation phase; the line loss levels are measured and power is allocated to the ADSL sub-carrier frequencies to obtain the lower of the maximum available bit rate, or the maximum configured bit-rate. The line is typically negotiated according to maximum and target signal to noise ratios configured into the DSLAM for the line being negotiated.
25. If a connection is negotiated at a lower bit rate that the line allows, it will have a better signal to noise ratio than a connection negotiated at a higher bit rate. This will make the connection better able to accommodate noise or other changes in conditions in the cable, and avoid renegotiation. Furthermore, the connection requires less power to maintain a high signal to noise ratio.

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<sup>3</sup> TelstraClear UBS Workshop Transcript - 11 Feb 2005  
<http://www.comcom.govt.nz/IndustryRegulation/Telecommunications/Wholesale/WholesaleDeterminatons/ContentFiles/Documents/WSUBS%20Workshop%20Transcript.pdf>

26. The following diagram illustrates how copper rate limiting affects overall power:



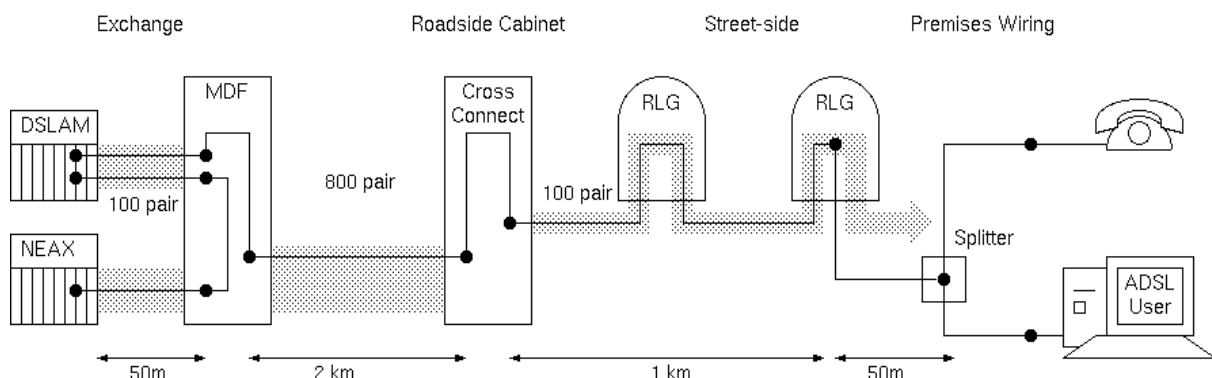
27. This diagram shows that constrained service uses the same power levels as unconstrained services at distances where the speed is limited by the available power rather than the configured data rate.

28. Adding noise into the cable, and therefore reducing the overall signal to noise ratio, will tend to move the above graph to the left, reducing the distance at which a given data rate can be delivered. The maximum distance that can be achieved at the minimum data rate is similarly affected.

29. ADSL signals themselves, along with other services within the same cable sheath can interfere with other signals; this is known as crosstalk. Operating at reduced data rates means that the power injected into the cable sheath is reduced in those pairs that have their bandwidth limited by the configured rate rather than the available bandwidth on the pair.

30. Reducing the data rate however only affects the power levels injected into lines close to the exchange, where the achievable data rate is significantly higher than configured data rate. At long distances, where the data rate is limited by the cable conditions, there is no reduction in power, and therefore no reduction in crosstalk.

31. The following diagram illustrates a typical connection from an exchange to an ADSL user's premises.



32. In this diagram, the pair from the DSLAM, carrying both ADSL and voice (from the NEAX PSTN exchange) is carried across the exchange building to the main distribution frame (MDF) via a 100-pair cable. It then crosses the MDF onto an 800-pair trunk cable connecting a cross-connect in a roadside cabinet. From the cross-connect, the pair enters a 100-pair cable laid down the street, entering a series of RLGs. Within the RLG (named after R. L. Grant, a Post Office engineer), typically located on every second section boundary, the cable is opened, and pairs broken out and joined to cables entering the user's premises. Other pairs are not broken out, and continue in the cable back underground to the next RLG. Such cables average approximately 1 km in length, and may be as long as 10 km. RLG cable distribution represents 36% of Telecom lines.<sup>4</sup> Other schemes include multi-core cables into high-density buildings and complexes, and hub-and-spoke architectures.
33. The length of a given pair is likely to be dominated by length of the cable run from the MDF (Main Distribution Frame) at the exchange to the first roadside cabinet. Pairs carrying high-bandwidth ADSL connections over short distances (and therefore potentially operating at higher power than if they were rate-limited) will usually not be sharing a sheath with long pairs that may be reach-impaired by crosstalk.
34. We must stress that cable architectures do vary widely in the Telecom network, depending on age, location, terrain, population density and so-forth. This is especially true of the cable beyond the first cross-connect. However, the nature of the trunk and tail type architecture does suggest that a cable sheath leaving the exchange will tend to contain short – medium length pairs, or medium – long pairs, but is less likely to contain a mixture of both short and long pairs.
35. While ADSL noise will raise the overall noise floor in a cable may be raised overall in a cable sheath, one should realise that crosstalk in a cable is largely a local effect. Power emanating from a single pair diminishes with distance from the pair in an inverse cube relationship, due to the fact that the power in the two wires of the pair cancels out with distance. Furthermore, the surrounding pairs have a shielding effect, so for the most part, a single noisy pair will have only have a significant effect on immediately adjacent pairs in the sheath. This allows for pairs within large multicore cables to be engineered for reach by locating them away from noisier pairs within the same sheath.

## **Effects of unconstrained downstream speed**

36. Telecom's submission claims that providing unconstrained downstream speed services will have several adverse effects on reach, useability, cost and stability.
37. Firstly, paragraphs 83 and 84 of Telecom's submission describe tests carried out by Alcatel, on the effect on reach of restricting line rates to 256 kbps, stating that an 800 foot (244 metre) improvement on reach would be obtained. The subsequent claim is made that if all services were rate shaped to 3 Mbps, 49,000 additional lines could be reached.
38. We have some difficulty understanding this claim, given that the majority of

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<sup>4</sup> Amos Aked Swift (NZ) Ltd, Telecom Access Model – Engineering Design Rules, December 2002  
<http://www.comcom.govt.nz/IndustryRegulation/Telecommunications/TelecommunicationsServiceObligations/ContentFiles/Documents/AAStelemaccessEngineeringDesignRules0.PDF>

Telecom's services are currently rate-shaped to 2 Mbps, and given the wide disparity between the 256 kbps tested by Alcatel and the 3 Mbps quoted by Telecom.

39. As observed above, unconstrained services synchronising at rates in excess of 3 Mbps are unlikely to be sharing a sheath with pairs where low speed service is barely achievable due to cable length.
40. Furthermore, ADSL services on such long runs are likely to be running at close to maximum power even at low data rates.
41. Secondly, the Telecom submission claims on paragraphs 88 through 101 that there is a risk of buffer overflows in DSLAMs due to unconstrained use. The submission discusses theoretical failure modes at some length.
42. Given that Telecom operates unconstrained downstream speeds on the majority of its business plans, and has done so on its residential plans in the past, we would expect Telecom to have produced operational data on this issue. The fact that they have not brought direct operational experience nor quoted external references in their submission suggests that this has not been found to be a significant problem.
43. Thirdly, paragraph 96 claims that the full downstream speed of 7.6 Mbps can not be fully utilised with a 128 kbps upstream channel, and that this will lead to "slow or unstable" experience for the end user.
44. Industry experience, and experiments carried out when researching our earlier submission<sup>5</sup> have shown that with modern TCP implementations, download speeds of 5 Mbps are easily achievable using a single TCP stream with a 128 kbps upstream channel. Telecom acknowledges in paragraph 97 that faster speeds are possible using non-TCP based services. One should also consider cases such as combinations of TCP downloads in parallel with datagram services such as streaming video which could fully utilise a 7.6 Mbps downstream channel.
45. In any case, the service would not be "slow" nor "unstable" due to the asymmetry. For those users fortunate enough to be able to synchronise at 7.6 Mbps, this simply means that the user may not experience transfer rates of 7.6 Mbps for any significant time. (Paragraph 129 of Telecom's submission states that only about 20% of lines will achieve this rate.)
46. Fourthly, paragraphs 102 through 104 suggest that a 50:1 contention ratio can not be achieved at current DSLAM port densities if calculated with all ports assumed to be capable of 7.6 Mbps. This reasoning fails to take into account that (according to Telecom) only 20% of ports configured at full rate will achieve 7.6 Mbps.
47. Paragraph 106 suggests using an arbitrary "average" downstream speed of 3 Mbps to determine the contention ratio. A contention ratio of 50:1 applied to 3 Mbps gives 60 kbps per user. While Telecom's reasoning differs from ours, this figure is very close to the 62 kbps per user suggested in our previous report.<sup>6</sup>

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<sup>5</sup> Krossos Report: InternetNZ Submission on the Draft UBS Determination, paragraph 31

<sup>6</sup> Krossos Report: InternetNZ Submission on the Draft UBS Determination, paragraph 28

48. As observed in our previous report, we find that a contention ratio alone is an unrealistic approach to achieving service equivalence, as for normal Internet services, traffic volumes do not have a direct correlation with access rate. It is not always necessary to provide 60 kbps per user to achieve service equivalence, however capacity should be available should overall traffic patterns change, or if an Access Seeker offering equivalent services to Telecom experiences heavier usage patterns than Telecom does.
49. Fifthly, Telecom points out (paragraph 132) that 20% of ADSL lines are served by Conklin mini-DSLAMs. These use a modular architecture to provide from 4 to 60 ports, and are subtended from central DSLAMs using from 1 to 4 E1 (2 Mbps) circuits.<sup>7</sup> Some of these are subtended using one E1, but Telecom is bringing the majority of these to 2xE1.
50. With 4 Mbps trunks, once ATM cell overhead is taken into account, the available bandwidth into an entire Conklin stack is only 3.5 Mbps. Clearly, even if a Conklin port synchronises at 7 Mbps, the user could not use that 7 Mbps because of the limitation on trunk capacity.
51. We do not believe that this affects the principle of an unconstrained downstream speed; rather it merely adds another factor to what the effective downstream speed can be for an “unconstrained” port. The “unconstrained” profile on a Conklin should be copper rate limited to a speed consistent with the trunk bandwidth, e.g. 3 Mbps for a Conklin with 2xE1 trunks.
52. Since Conklin mini-DSLAMs are intended for use in remote cabinets, we believe that the reduced speed for these is appropriate, as such cabinets would not normally have long trunk cables between the mini-DSLAM and the first user drop. There may be a higher likelihood of mixtures of long and short pairs in sheaths originating from such cabinets.

### **Recommendations as to downstream speed**

53. We do not believe that Telecom has provided a strong argument against providing an unconstrained downstream UBS service.
54. Nevertheless, we believe that many providers will wish to offer constrained bit rate services, for product placement reasons, and also to provide more consistently reliable services.
55. We believe that where an Access Seeker would rate-shape ADSL service, they may choose to apply appropriate copper rate shaping as well as rate shaping within its network to achieve maximum reliability. The DSLAMs have sufficient available (or existing) profiles to do this.
56. Unconstrained profiles on remote DSLAMs where trunk capacity is limited (eg Conklin mini-DSLAMs with 2xE1 trunk circuits) may be rate limited according to the trunk bandwidth; this will have the additional effect of improving reach in remote cabinet situations.
57. Constrained services must be constrained at a rate compatible with layer 3 traffic

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<sup>7</sup> <http://www.conklin-intracom.com/pdf/AL20DS0103.pdf>

shaping at the specified speed.

58. We believe that reach issues should be addressed using ADSL 2 and/or by tuning of DSLAM profiles to appropriate target and maximum signal to noise ratio parameters. Reach can also be improved in specific cases by engineering; eg arranging pairs in the sheath so those long pairs are not adjacent to pairs that may interfere.

## **Monitoring and testing**

59. Dr Murray Milner of Telecom described<sup>8</sup> the ADSL testing and monitoring procedures.

60. Currently, 26 probes are available for use, with another 100 on order. Each probe is essentially an ADSL modem with testing and reporting capabilities built in. The probes are attached to designated test lines, attached to DSLAM ports, and can be used to make end-to-end tests from the probe to a BRAS located either within the Telecom network or at the Access Seeker.

61. Probes can be moved between services (eg UBS, JetStream, UPC etc) without physical reconfiguration. They can be moved between DSLAMs within an exchange by moving patch wires on the MDF, or can be redeployed at different external locations. Clearly, non-physical reconfiguration can be done rapidly, while changes to probe location is labour intensive and could not be performed rapidly.

62. According to Dr Milner, Telecom has engaged Massey University to provide guidance on placement of probes and statistical analysis of confidence levels that can be attained by use of such probes. The results of this work are expected in approximately one month.

63. At present, there are approximately 650 exchange-based DSLAMs and 1,000 mini-DSLAMs in use. Mini-DSLAMs represent approximately 20% of all ADSL ports.

64. We believe that with 126 probes, high confidence levels can be attained for factors associated with individual DSLAMs and their associated network infrastructure. For line performance factors, lower confidence levels would have to be expected, however we believe that careful choice of probe location could give a good spread of line characteristics and therefore a higher level of confidence than raw numbers would suggest.

## **Recommendations as to monitoring and testing**

65. We welcome Telecom's engagement of expert assistance in the analysis and configuration of the ADSL testing and reporting process.

66. We believe that such guidance will allow Telecom to offer better than the 95% confidence levels specified in the Draft Determination.

67. We recommend that the Commission work with Telecom and its consultants to improve on the confidence levels specified by the Draft Determination.

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<sup>8</sup> Meeting between Don Stokes and Dr Murray Milner, 7 June 2005