SHDSL Baseline Proposal

Performance analysis

Supporters

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Contents

802.3ah D1.0 has two proposed long-reach copper Ethernet PHYs

- SHDSL (2BASE-TL)
- ADSL – Annex J (2PASS-TL)

Examine

- Performance results
- Theory & practice
  - In theory, theory and practice are the same
  - In practice, they are different
- Myths & realities
- Top Ten (plus one)

Performance: Assumptions

- Use same loop and interferers for both
- Use same set of interferers as SHDSL + a couple to match Artman_copper_1_0702
- 6 dB of margin / 5 dB Coding Gain for both
- No implementation loss
- The “regular & publicly available set of assumptions” (T1.417, G.992.1, G.991.2, G.992.3) (see back-up slides for list)
- Enhanced SHDSL with TC-32PAM

Interferer Set for North America

49-self	24 T1 + 24 HDSL	24 ADSL + 24 self
39-ADSL	24 T1 + 24 HDSL	24 HDSL + 24 self
49-ISDN	24 T1 + 24 self	
49-HDSL	24 ADSL + 24 HDSL2	
24 ISDN+ 24 self	24 ADSL + 24 HDSL	

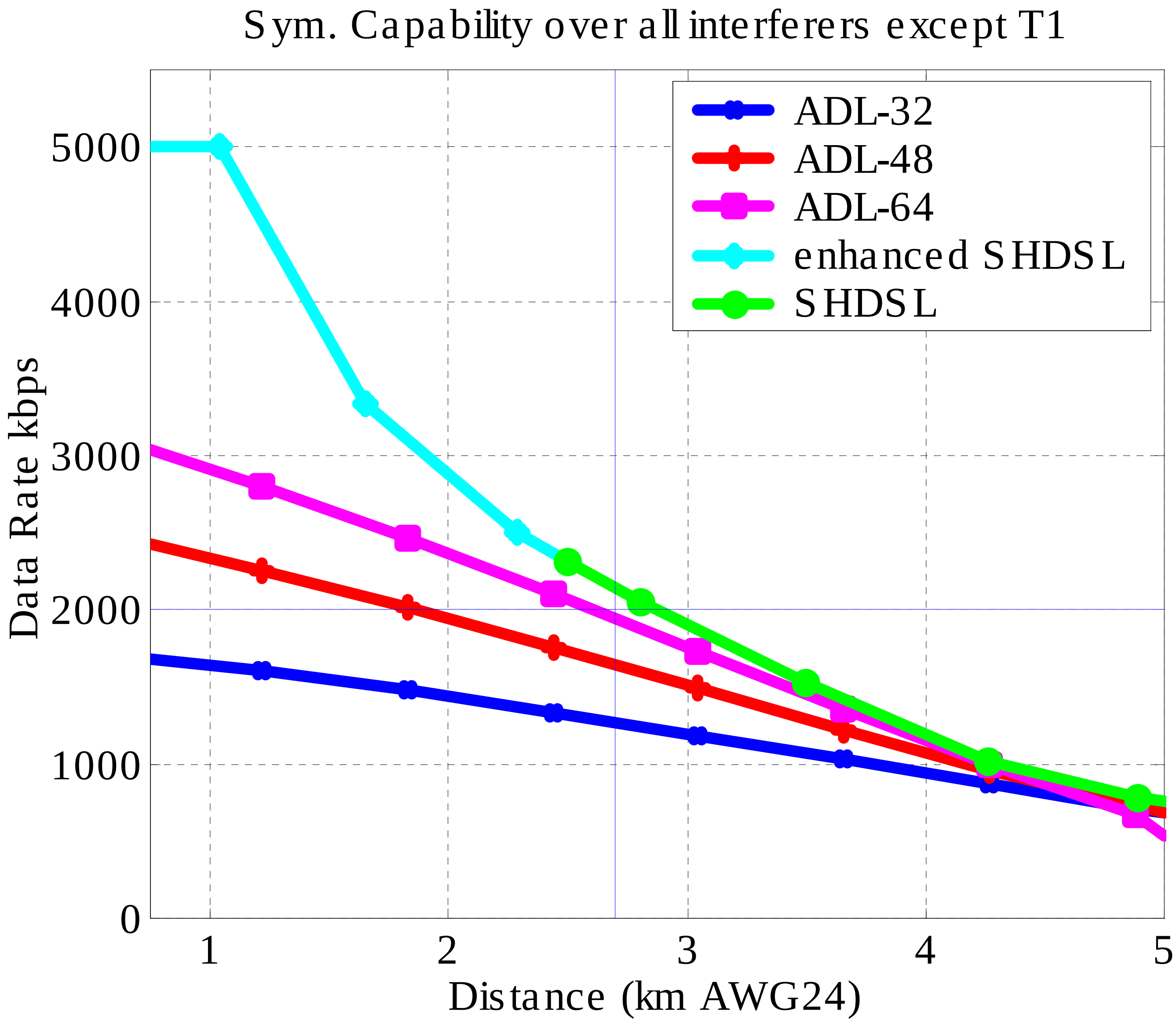
Reality about business loops

- Derived from FCC – 02 –33A1 Feb. 6, 2002
  (available at www.fcc.gov, perform search on document number)
  - As of June 2001 Broadband access of Business/Institutions
    (Appendix C, at least 200kbps in one direction, Table 1 – Table 3)
    - 11 % ADSL
    - 53 % other wireline (symmetric services)
    - 10% cable modem + 25 % fiber + 1% wireless or satellite
  - Out of the xDSL service deployment, 83% of lines are non-ADSL and include T1, HDSL, HDSL2, SDSL 2B1Q etc…
  - Noise models with symmetric services as disturbers are most relevant.
- This is **NOT** the residential binder
  - Cannot ignore T1 & symmetric services
  - Co-existence with existing business services is key

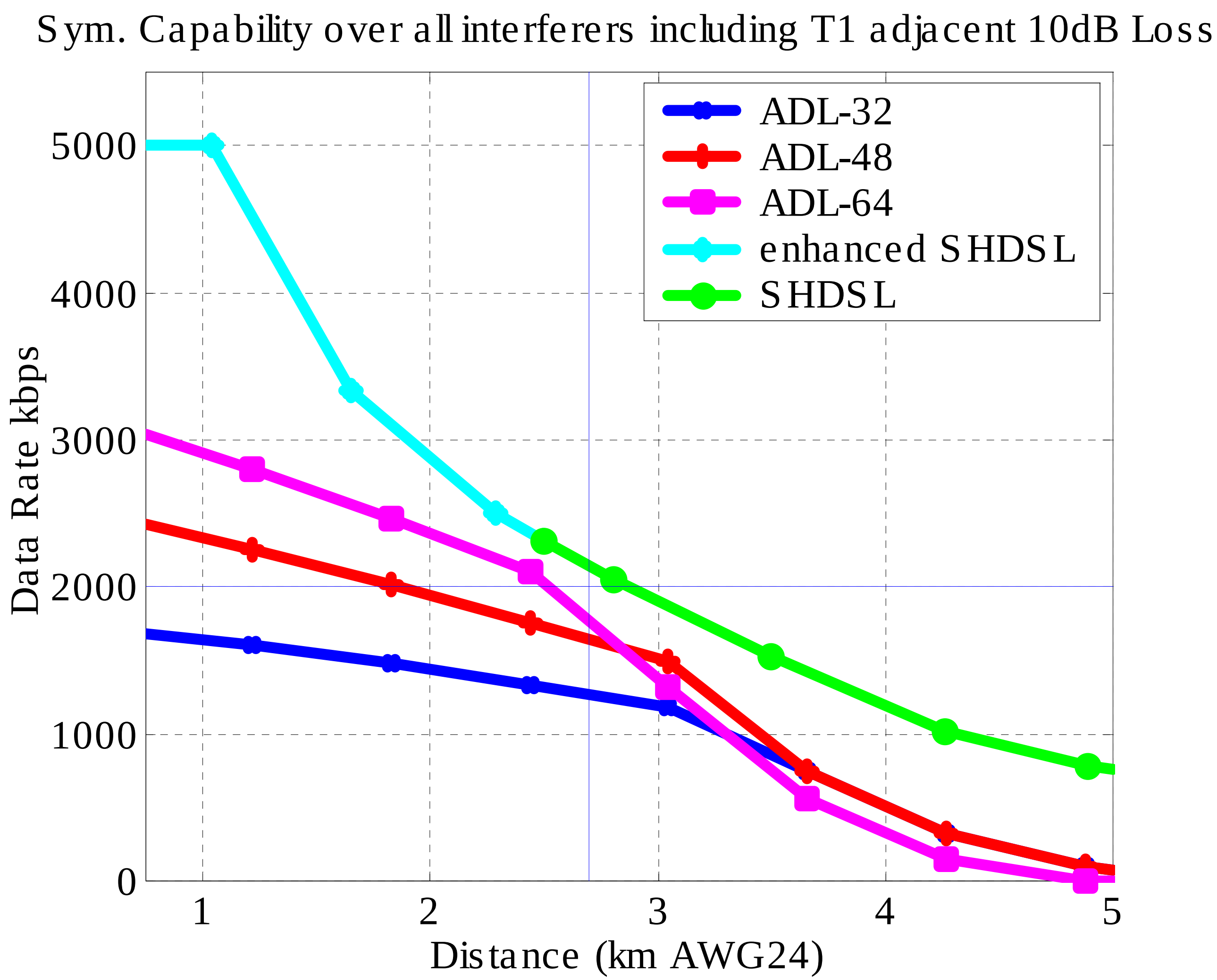
Symmetric capability

- Symmetric = minimum of upstream and downstream
- Take the minimum data rate achievable across a set of interferers
- Performance will ALWAYS be equal or better than this
- Upstream is usually worst case for asymmetric PHYs
- The following two graphs show the theoretical results. They do not take the efficiency of the modem into account.

All interferers except T1



All interferers+ T1 adjacent 10dB

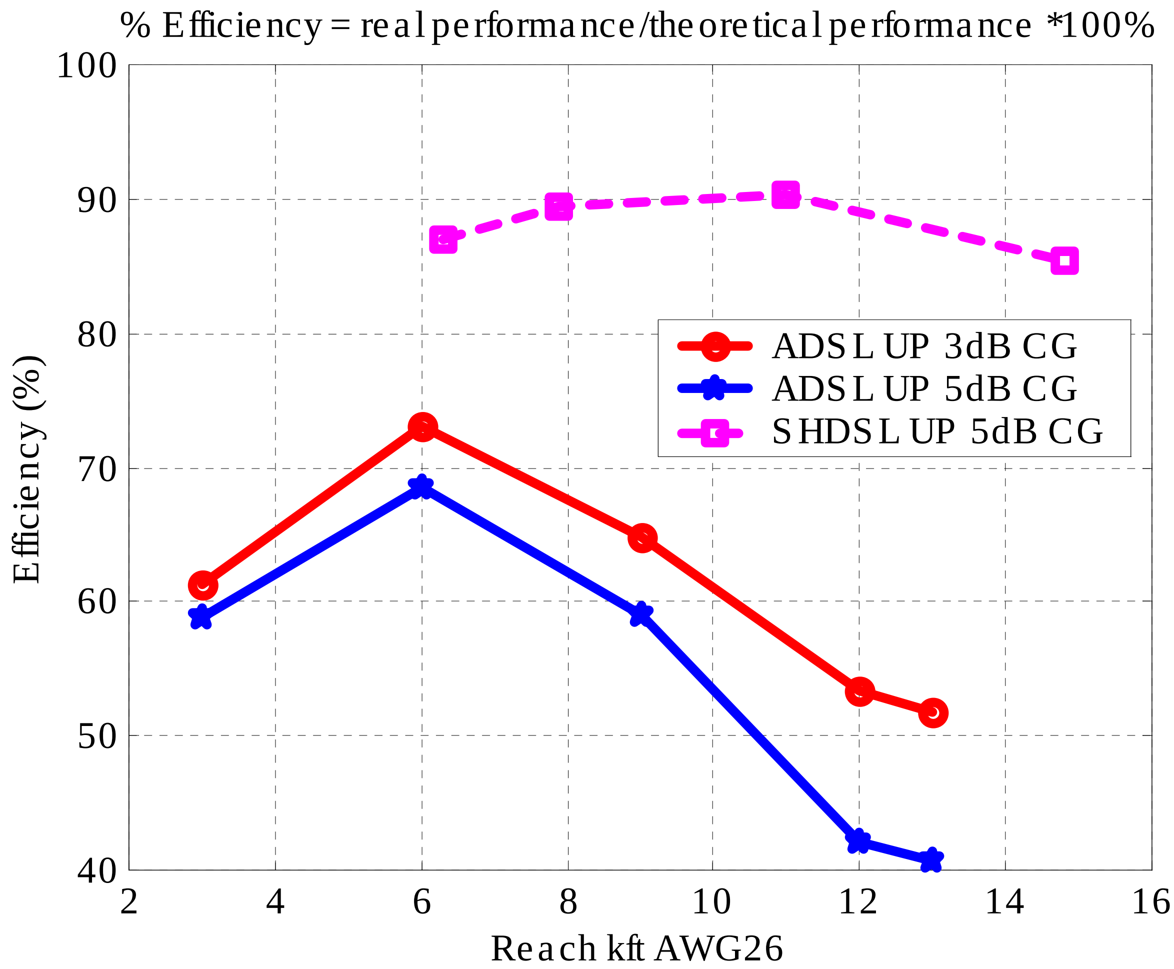


Co-existence with existing business services is required
ADL cannot meet requirements in most realistic scenario

Comparing theory & practice

- How close will the real performance be to the theoretical one?
- Look at modem reach test required from ADSL -> TR48 & DSL 2002.219 (available from DSL forum web site)
- Look at modem reach test required from SHDSL -> G.991.2
- Use 24 HDSL case for TR48 (sec. 8.1.2) and performance from G.991.2 table A-1
- Plot upstream efficiency = (practice data rate) /(theory data rate)* 100% (see derivation in back-up slides)

Comparing theory & practice



There is a significant gap for ADSL between theory and performance testing.
*Remember: practice = theory * efficiency*

Myths about SHDSL

- SHDSL cannot run over POTS using splitters: **WRONG**
- SHDSL is a symmetric only system: **WRONG**
- SHDSL cannot gain from MIMO (Multiple Input Multiple Output) or cross-talk cancellation: **WRONG**
- For long reach, PAM is a less efficient line code than DMT: **WRONG**

Realities about SHDSL

- Choices were made when SHDSL was designed to optimize it for symmetric rate delivery & robustness: **TRUE**
- Other options can be implemented: **TRUE**

Top Ten (plus one)

	Criteria		ADSL Annex J	SHDSL
1	Availability		×	✓
2	Interoperability		Future	✓
3	Performance	Asymmetric	✓✓	✓
		Symmetric	✓	✓✓
		Meets Objective	?	✓
		Repeaters	×	✓
		Can be expanded to higher symmetric rates	×	✓(*)
(*) Active work on enhanced SHDSL in ITU & ANSI				

Top Ten (plus one) (ctnd)

	Criteria		ADSL Annex J	SHDSL
4	Spectral compatibility	Obeys Spectral Compatibility criteria	✓	✓
		Basis System of T1.417 (i.e. protected)	×	✓
5	Standards	ANSI Standard	×	✓
		ETSI Standard	(informative annex)	✓
		ITU standard	✓	✓
6	Telco operator support		?	✓
7	Cost		Similar	

Top Ten (plus one) (ctnd)

	Criteria		ADSL Annex J	SHDSL
8	Functionality distinct from VDSL (*)		?	✓
9	Satisfies 5 criteria		×	✓
10	Ease of Use	Residential	✓ ✓(**)	✓
		Business	?	✓ ✓

(*) If an asymmetric service is needed, start from VDSL and use upstream 0 and part of downstream 1. At first, it will be a separate PHY but can be integrated. SHDSL is Echo-cancelled, Long Reach and distinct from VDSL.
(**) Assuming operation over POTS adopted

The (plus one) of the Top Ten

	Criteria		ADSL Annex J	SHDSL
11	Losers if we do not make a decision (*)		Everyone loses	

(*) Losers because might get into line code war (see VDSL), slow down other standards, slow down optics, initial objective of EFM copper was short reach, operators asked for longer reach, nail that decision and then move on to solve VDSL line code.

Conclusions

- Both SHDSL & ADSL are great systems conceived for different purposes.
- SHDSL has superior symmetric capabilities both in theory & practice.
- Test performance is close to 90% of theoretical performance for SHDSL, between 40 and 70% for ADSL.
- Bottom line: SHDSL meets the objective under all conditions both in theory and practice.

Additional slides

Simulation Assumptions

- Same noise/ and same loop for SHDSL & ADL
- 6dB margin, 5dB Coding Gain, -140dBm/Hz noise floor, 0dB implementation loss for both.
- Loop is AWG24 as per spectrum management table B.6
- ***Computation of margin***
- Used same procedure as for (T1.417) spectrum management document for ADL and SHDSL.
- For ADL, 6 dB of margin using DMT capacity equation with 1 to 14 bits per carrier (similar to Table A.6 of T1.417).
- For SHDSL, 6dB of ideal DFE margin using ideal DFE equation (similar to Table A.3 of T1.417). SNR required for Coded 16-PAM @ 0 dB margin is 27.71 dB
- For enhanced SHDSL, 6dB of ideal DFE margin using ideal DFE equation (similar to Table A.3 of T1.417). SNR required for Coded 32-PAM @ 0 dB is 33.80 dB.
- ***Transmit PSD:***
- ADL upstream PSD: used nominal PSD (i.e. mask as per table J.1 of G.992.3 minus 3.5dB). Used carriers 1 to 31 for ADL-32, 1 to 47 for ADL-48 , 1 to 63 for ADL-64, etc…
- ADL downstream PSD: used nominal PSD for non-overlapped spectrum operation with passband starting at 254kHz (as described in section J.1.3 of G.992.3 and referring to Fig. B-2.). Used carriers 65 to 255.
- SHDSL PSD: nominal PSD defined as per section A.4.1. of G.991.2. All rates below and including 2312kbps.
- ENHANCED SHDSL PSD: nominal PSD as per section A.4.1. of G.991.2 with 4 bits per symbol (Coded 32-PAM, fsym=rate/4). All rates above and including 2500kbps.

Simulation Assumptions

Interferer set:

'49-self': 49 self-interferers

'39-ADSL': 39 FDD ADSL interferers as per Fig. A-2 and A-3 of G.992.1

'49-DSL': ISDN as per A.3.3.7 of G.991.2

'49-HDSL': HDSL 2B1Q 784kbps as per A.3.3.1 of G.991.2

'24-DSL+24-Self': ISDN + self interferer

'24-T1+24-HDSL2': T1 AMI as per A.3.3.2 of G.991.2, HDSL2 PSD as per A.4.2.1 & A.4.2.2 of G.991.2

'24-T1+24-HDSL': T1 + HDSL

'24-T1+24-Self': T1 + self

'24-T1A15+24-HDSL2', '24-T1A15+24-HDSL','24-T1A15+24-Self': same as above but T1 is in an adjacent binder assuming 15.5 dB additional attenuation due to "adjacent binder effect and averaging factor which accounts for non-collocation of the T1 and ADSL terminals" as per T1.413 issue 2.

'24-T1A10+24-HDSL2','24-T1A10+24-HDSL','24-T1A10+24-Self': same as above but assuming the regular 10 dB attenuation for binder separation.

'24-ADSL+24-HDSL2': 24 FDD ADSL and 24 HDSL2

'24-ADSL+24-HDSL': 24 ADSL and 24 HDSL

'24-ADSL+24-Self': 24 ADSL and 24 self

'24-HDSL+24-Self': 24 HDSL and 24 self

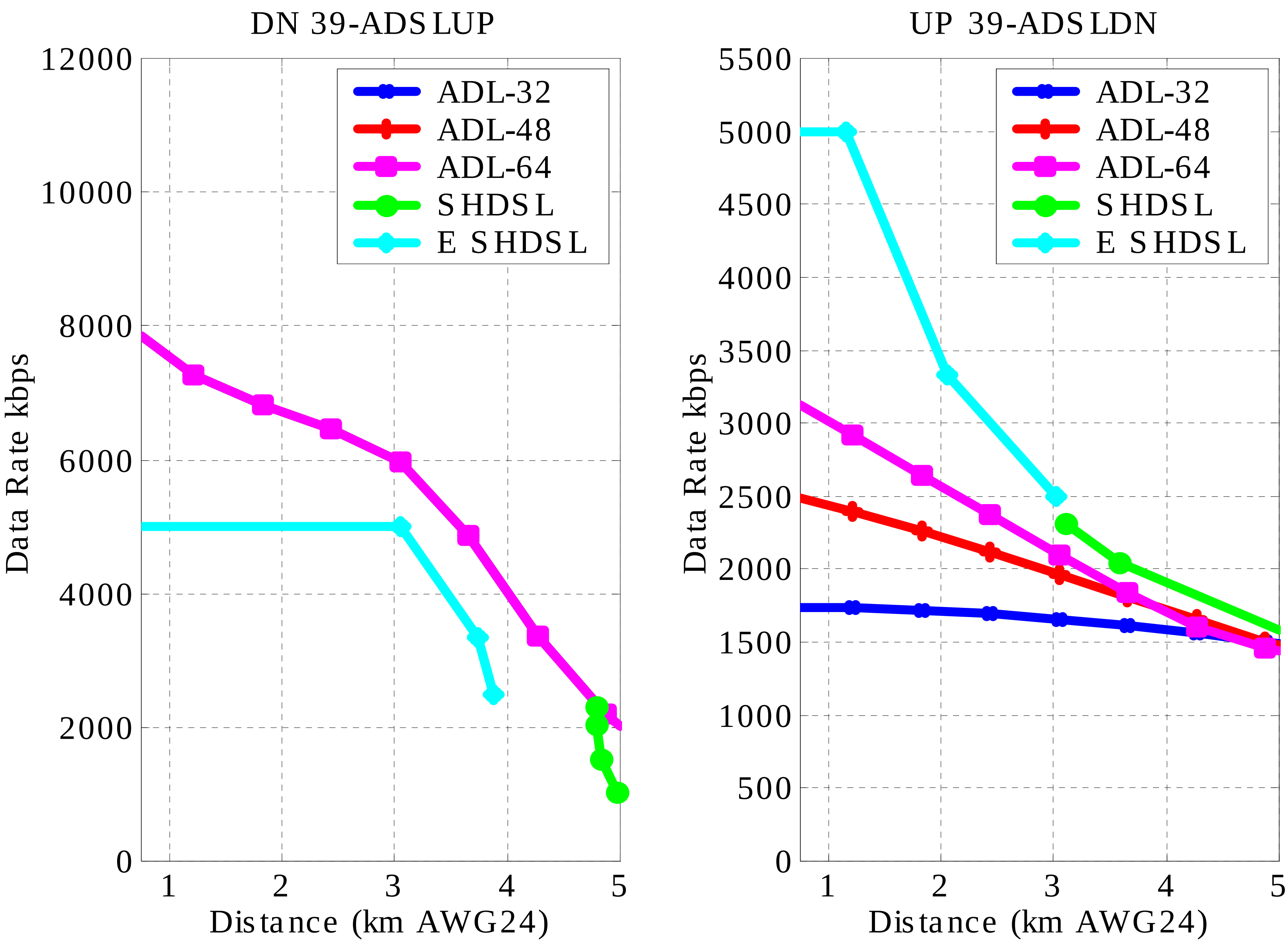
One-piece model for NEXT is used (A.3.3.8 of G.991.2)

Mean PSD method is used to add interferers (A.3.3.9 of G.991.2)

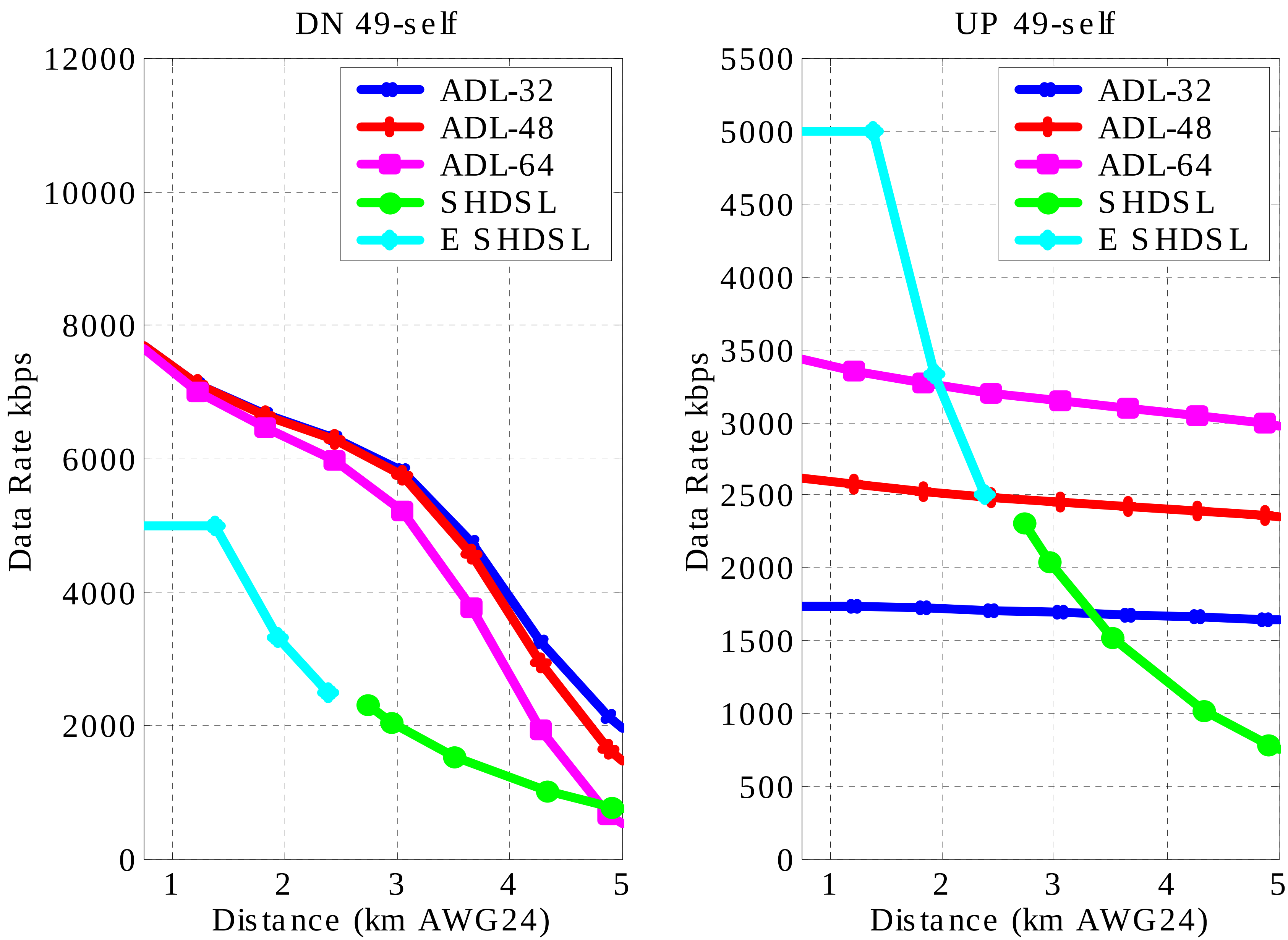
The exhaustive simulation results were sent on the exploder on 7/5/02. They can be obtained by searching the email archive for copper_ADLandSHDSLPerformance. The results for 49-self and 39-ADSL have changed slightly and are reproduced here. The ADL DN PSD was changed from a brick wall to the description given in the standard. This will reduce the ADL UP results for self NEXT slightly. For the 39-ADSL case, the FEXT was initially computed on AWG26 rather than AWG24, both ADL and SHDSL performance are slightly reduced.

There is a gap between the reach of the lower enhanced SHDSL rates and the higher SHDSL rates. This is due to the fact that enhanced SHDSL is based on Coded 32-PAM which requires roughly 6 dB more SNR for the same margin. This gap is very obvious in low noise conditions such as the results for SDSL DN with 39-ADSL UP as interferer. The use of C-16 for enhanced SHDSL will smooth out the curve. Results for C-16 are not included because producing the results would take a long time. The gap was filled for the symmetric performance graphs.

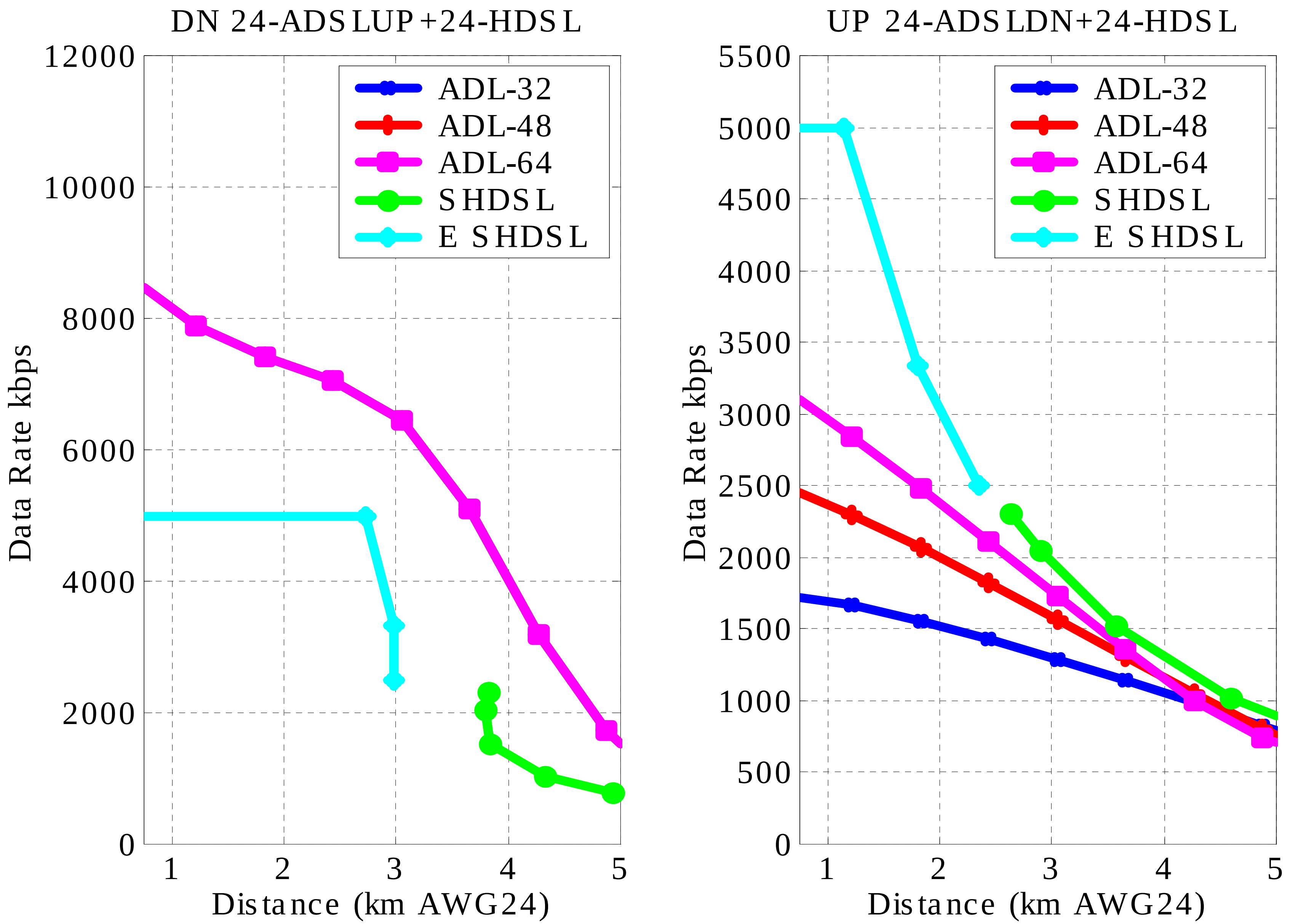
Sample Results: 39-ADSL



Sample Results: 49-self



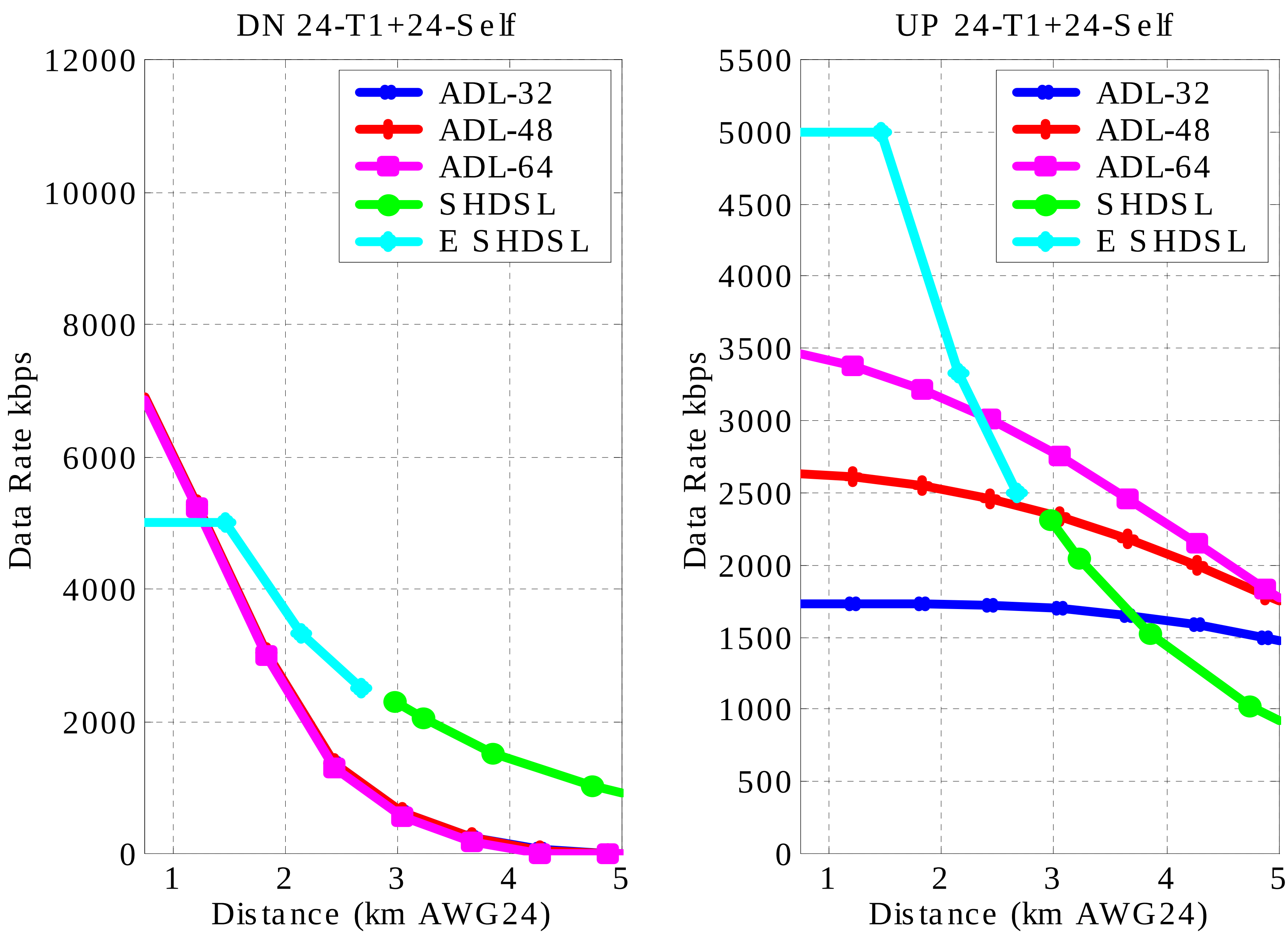
Sample Results: 24-ADSL + 24 HDSL



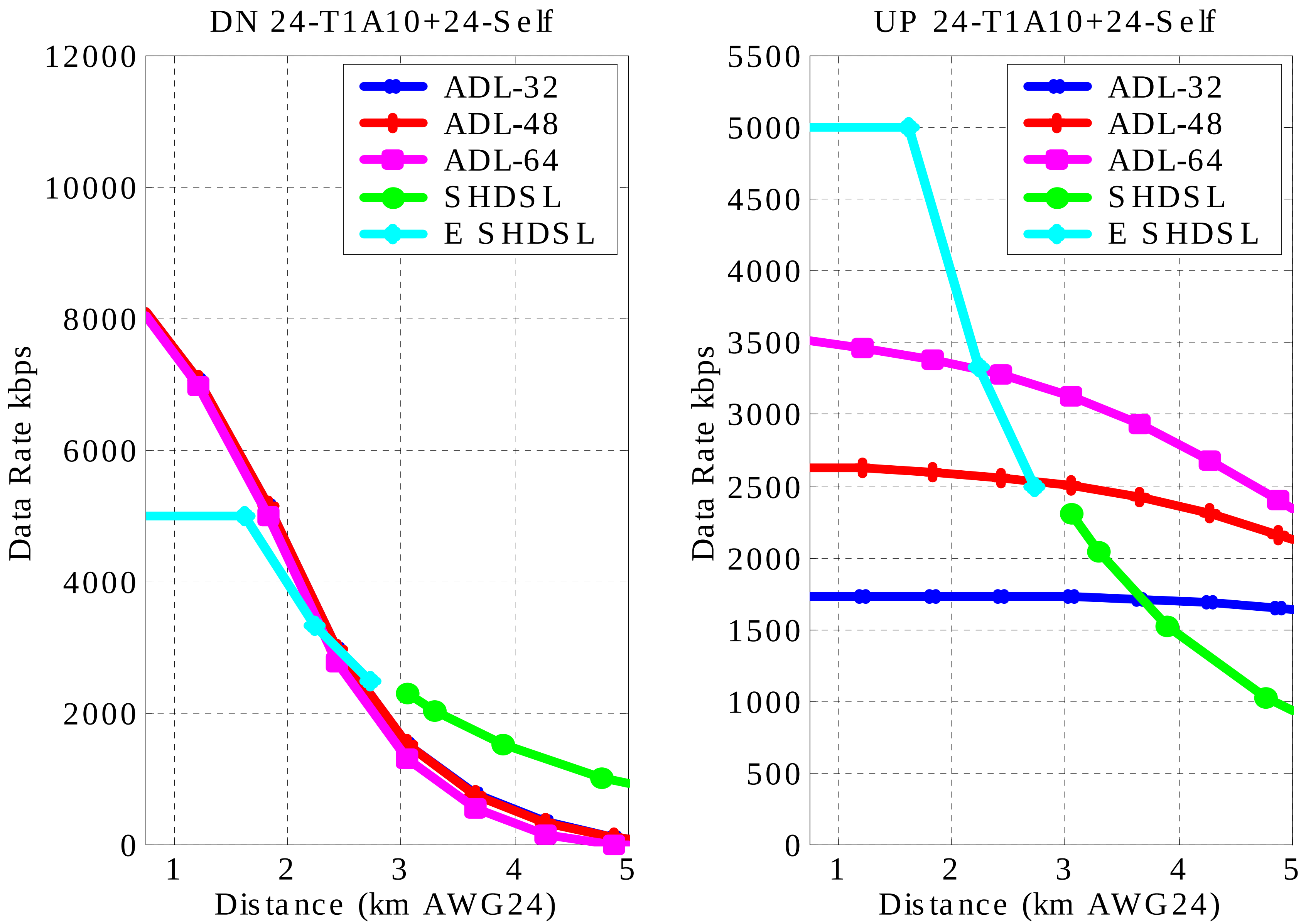
T1, the secret FDD system killer

- 3 level of interference
  - Same binder
    - 0dB attenuation (used for SHDSL)
  - Different binder and CPE separation
    - 15.5dB attenuation (used for ADSL)
  - Different binder
    - 10dB attenuation (regular assumption)

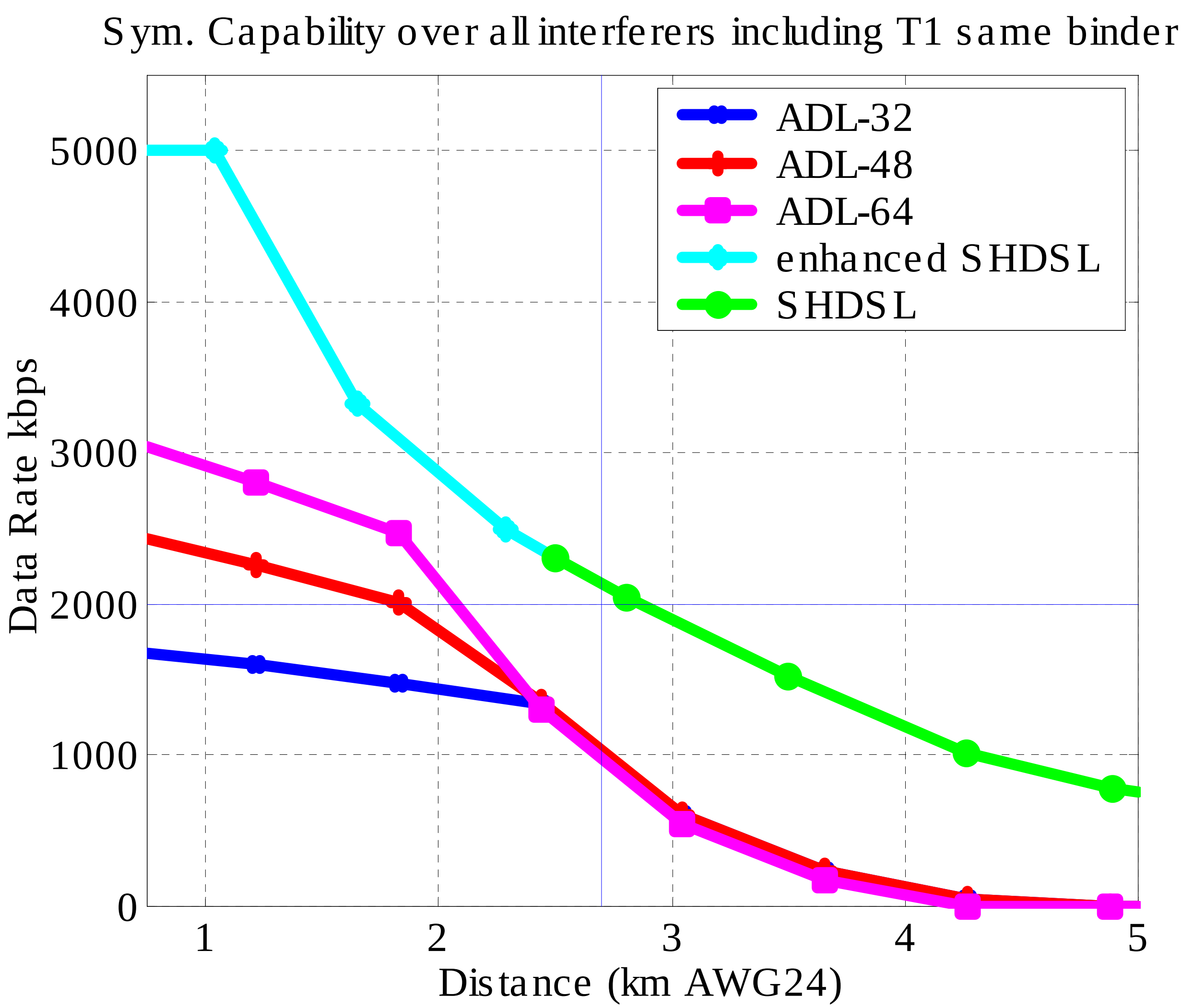
Sample Result: T1-same binder



Sample Result: T1-adjacent binder(10dB)



Overall impact of T1 (same binder)



Use VDSL rather than ADSL if asymmetric delivery is needed

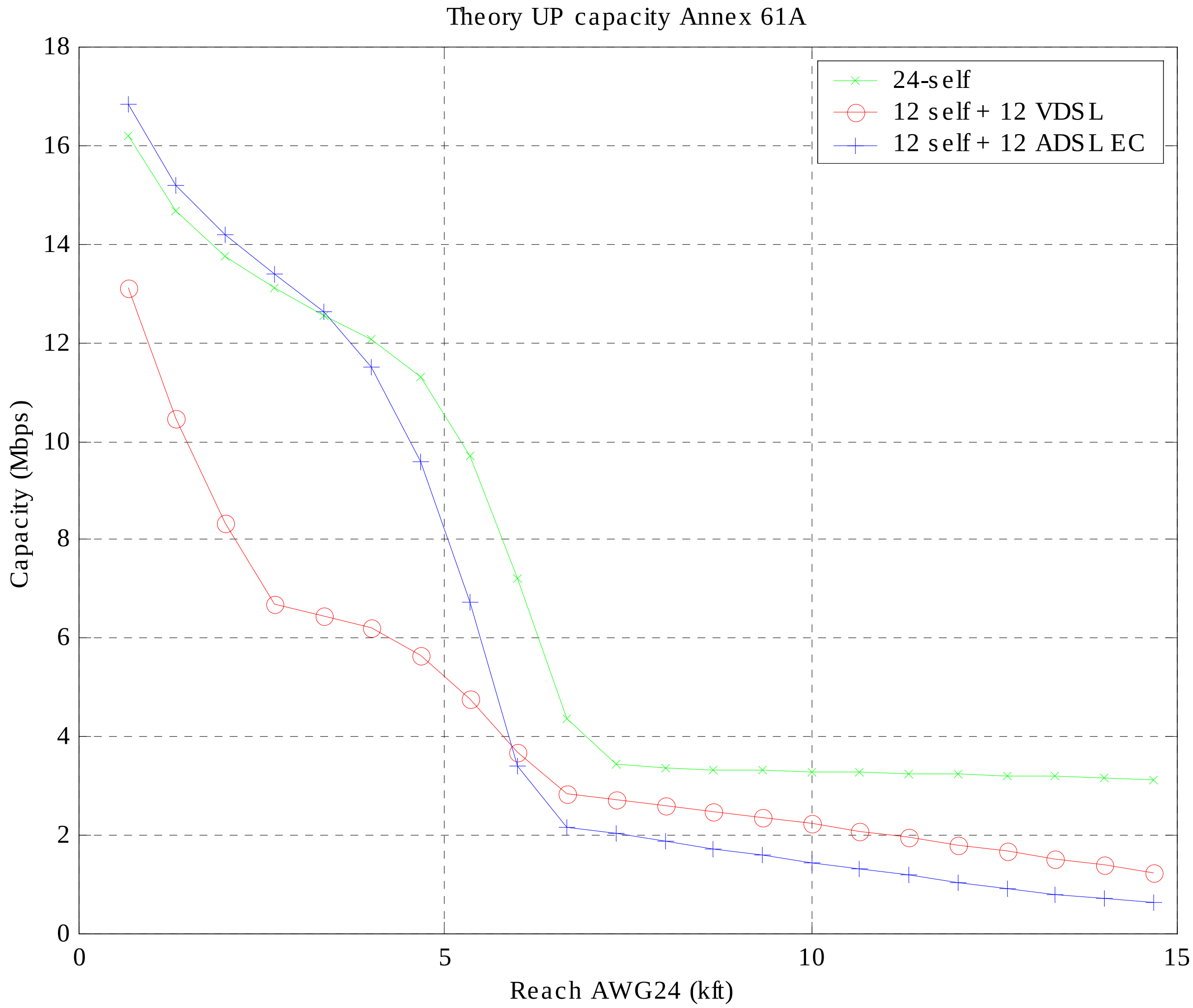
- If the end game is to have VDSL everywhere and a minimum of PHYs
- VDSL includes asymmetric capability of ADSL (with upstream 0).
- Various ideas have been juggled for VDSL LR based on other spectra. Look at annex 61A

- Analysis is based on details given in T1E1.4/2002-204. "A spectrally compatible band plan with VDSL plan-998, for use in symmetrical applications like 10MDSL or EFM". Behrooz Rezvani,Sam Heidari, Vahbod Pourahmad, John Cioffi, Chris Hansen, Ed Eckert, Massimo Sorbara, Sedat Oelcer. Denver, Colorado. August 2002. T1E1.4/2002-203 discusses performance. The same parameters as 203 were used to compute the performance. PSD from Table 2 of 204, Upstream Freq are [25.875 to 299.7188] and [2700.7 to 4399.8]kHz. CG 5.1dB, Margin 6dB, Max/Min bits per bin 1:14. –140dBm/Hz NF. Self NEXT performance matches that of 203, fig. 17. We also get the same VDSL SC results shown in annex 61A and 204. The performance shown represents the theoretical capacity minus the cyclic prefix of a DMT system and is not achievable in practice (does not take into account OH, nor guard bands, etc…).

A word about Annex 61A as VDSL LR

- Another spectral plan for VDSL with "longer reach capability" claims
- Great upstream with self-NEXT
- BUT : Upstream halved from 10 to 5 Mbps @ 5kft when VDSL 998 is present
- In theory, annex 61A works, in practice need to root out VDSL for it to work
- Finding a better PSD will not be an easy job because of the shackles of Spectrum management

UP Theoretical Capacity of 61A



Efficiency calculation details

The G.992.3 performance section references TR48 from the DSL Forum. TR48 lists a set of distances, interferers and expected bit rates that a modem is suppose to pass. DSL2002.219 is a proposal that asks to raise the bar on some of the performance results. We pick section 8.1.2 which lists performance levels for 24 HDSL with −140dBm/Hz, 6dB margin. We then compute the theoretical capacity with the regular set of assumptions used for ADSL (the cyclic prefix is deducted from the theoretical numbers) and compare both. Note that the TR48 number is a net data rate that does not include overhead while the theoretical number shows the maximum achievable capacity. The efficiency number is a measure of how efficient a system is in producing a net data rate. ADSL does not mandate the use of the trellis coder. Therefore 2 coding gain are simulated: 3 dB (assumes RS only) and 5 dB (assumes both RS and Trellis). When computing the efficiency, we use the DSL2002.219 numbers (this will give a higher efficiency for ADSL than the TR48 numbers)

ADSL Upstream (kbps)

kft AWG26	TR48	DSL2002.219	Simu 3dB CG	Simu 5dB CG
3	800	800	1305	1359
6	672	736	1006	1075
9	416	448	692	760
12	160	192	360	455
13	96	128	247	315

Example: efficiency of ADSL @ 9 kft and 3dB CG is 448/692 *100 = 64.8 %

We do the same thing with the performance expectations from SHDSL G.992.1 Table A-1

We compute the theoretical performance assuming the regular set of assumptions. Margin is 5dB, Noise floor −140dBm/Hz.

SHDSL Upstream (kbps)

Kft AWG26	Interferer	Table A-1	Simu (5dB CG)
6.3	49-self	2304	2650
7.9	39 HDSL2	1544	1725
11	49-HDSL	768	850
14.8	24 self + 24 ISDN	384	450

Example: efficiency of SHDSL @ 11kft = 768/850*100=90.3%