Long Reach PHY proposal: SHDSL

Decision Time

Supporters

- Marc Kimpe (Adtran) (main contact)
- Matt Squire, Steve Jackson (Hatteras Networks)
- Craig Easley (Extreme Networks)
- Scott Simon, Bruce Tolley (Cisco Systems)
- Walter Juras, Zion Shohet (Infineon)
- Edward Beili (Actelis)
- George Eisler, George Cravens (Mindspeed)
- Eyal Barnea (Metalink)
- Jim Apfel (Electriphy)
- Paul Tuong, Kishan Shenoi (Symmetricon)
- Massimo Sorbara (GlobespanVirata)
- Richard Brand (Nortel Networks)
- David Law (3COM)
- Nelson Zagalsky (ADC)

Let's remember how we got here…

- In 2001…
  - EFM-Cu focused on Ethernet over VDSL
- In 2002…
  - EFM-Cu hiccups, carriers and others raise concerns that VDSL missing long reach component
  - Culminates in wei_1_0302.pdf
    - aka *VDSL and enhanced-SHDSL as PHYs for EFM Copper*
  - Leads to adoption of new long reach objective:
    - 2M @ 2700m
- And now 2003…
  - Need to remember why the long reach objective came about

Which LR PHY ?

- Both SHDSL & ADSL are great systems
- Find out which PHY is the most appropriate for the Long Reach objective
- Examine the 5 criteria
  - Broad market potential
  - Compatibility
  - Distinct identity
  - Technical Feasibility
  - Economic Feasibility

PAR 1: Broad Market Potential

a) Broad sets of applicability.

b) Multiple vendors and numerous users.

c) Balanced costs (LAN versus attached stations).

Does SHDSL satisfy PAR 1?	
1a)	Yes
1b)	Yes
1c)	Yes

Broad market potential

- In order to have a broad market potential, one needs customers
- The customers for EFM are the Telcos
- A significant number of Telcos prefer a PHY based on SHDSL for the long reach (see companion slide for list)

The importance of timing…

- Like it or not, the business environment is where long reach EFM is needed **now**
- Why ?
  - Have applications: VLAN, LAN extension, remote office connectivity
  - Have budgets to pay for service
  - Telcos can justify cost upgrade in equipment

Broad market potential requires ubiquitous deployment

- Ubiquitous deployment in the local loop means dealing with neighboring systems.

1. Having acceptable egress levels into other systems
   - **SHDSL is a basis system** in T1.417, easing its deployment in North America
     - ADSL Annex J is not (see spectral compatibility section)
   - **SHDSL is already approved** in Europe, China, Australia,…
     - ADSL Annex J is not (see spectral compatibility section)
2. Being robust to ingress from other systems
   - **SHDSL can deal with business deployments**

     Business environment involves symmetric interferers & robustness (see deployment section, slides 21-24). SHDSL has excellent immunity to other symmetric systems.
     - Annex J does not (see performance section)

Let's look at the word "broad"

	SHDSL	ADSL2 Annex J	ESHDSL	Annex J & POTS
North America	**Deployed** & Protected	Never Deployed	Never Deployed	Never Deployed
Cont. Europe	**Deployed**	TBD	TBD	TBD
UK	**Deployed**	Not in its present form	TBD	TBD
Far East	**Deployed**	TBD	TBD	TBD
Australia	**Deployed**	TBD	TBD	TBD

Protected: minimum performance is protected.
Never Deployed: obeys SpM document requirements but never deployed
Not in its present form: UK ANFP does not allow annex J PSDs beyond ADL-32, could modify PSDs but would take performance hit
TBD: needs to go through regional regulatory body process

What about residential?

- How is the residential market currently served?
  - Ultra long reach -> dial up
    - No proposal or objective for EoModem
  - Long reach -> ATM over ADSL (EoATMoADSL)
    - Already operationalized and commoditized
  - Long reach -> cable modem
    - Mostly North American reality
  - Short reach -> no broadly adopted standard solution
    - EFM, VDSL is most favored candidate

What about residential?

- How might the residential market be served in the future?
  - Long Reach symmetric (or high upstream bandwidth) may be served by SHDSL
  - Installation of new links will either be fiber or wireless not copper
  - Greenfield Long Reach may be served by EoVDSL with fiber
  - Reality check: wherever ADSL (or cable modem) already exists, ATM (or DOCSIS) will be preferred

PAR 2: Compatibility

a) Conformance with 802.1D, 802.1Q, 802.1f.

b) Conformance with 802 overview and architecture.

c) Compatible managed object definitions.

Does SHDSL satisfy PAR 2?	
2a)	Yes
2b)	Yes
2c)	Yes

PAR 3: Distinct Identity

a) Substantially different from other IEEE 802 standards.

b) One unique solution per problem (no two solutions to a problem).

c) Easy for the document reader to select the relevant specification.

Does SHDSL satisfy PAR 3?	
3a)	Yes
3b)	Yes
3c)	Yes

How many PHYs?

- Asymmetric LR capabilities
  - If one wants asymmetric long-reach DSL with POTS, use VDSL – it can be just as good
  - VDSL and ADSL are **not distinct** as VDSL band plan covers both
- Symmetric LR capabilities
  - Standardized VDSL band plans are not designed for Long Reach symmetric and are not designed to deal with LR business interferer mix.
  - VDSL and SHDSL are distinct

PAR 4: Technical Feasibility

a) Demonstrated system feasibility.

b) Proven technology, reasonable testing.

c) Confidence in reliability.

Does SHDSL satisfy PAR 4?	
4a)	Yes
4b)	Yes
4c)	Yes

Technical Feasibility

Examine:

- Performance results
- Deployment realities
- Spectral compatibility restrictions
- Differences between theory and practice
  - In theory, theory and practice are the same
  - In practice, they are different

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

Note: enhanced SHDSL is still debated within ITU. Upper rate of TC-32PAM ESHDSL will be at a minimum 3Mbps, 5 Mbps at a maximum. (see back-up slides).

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	

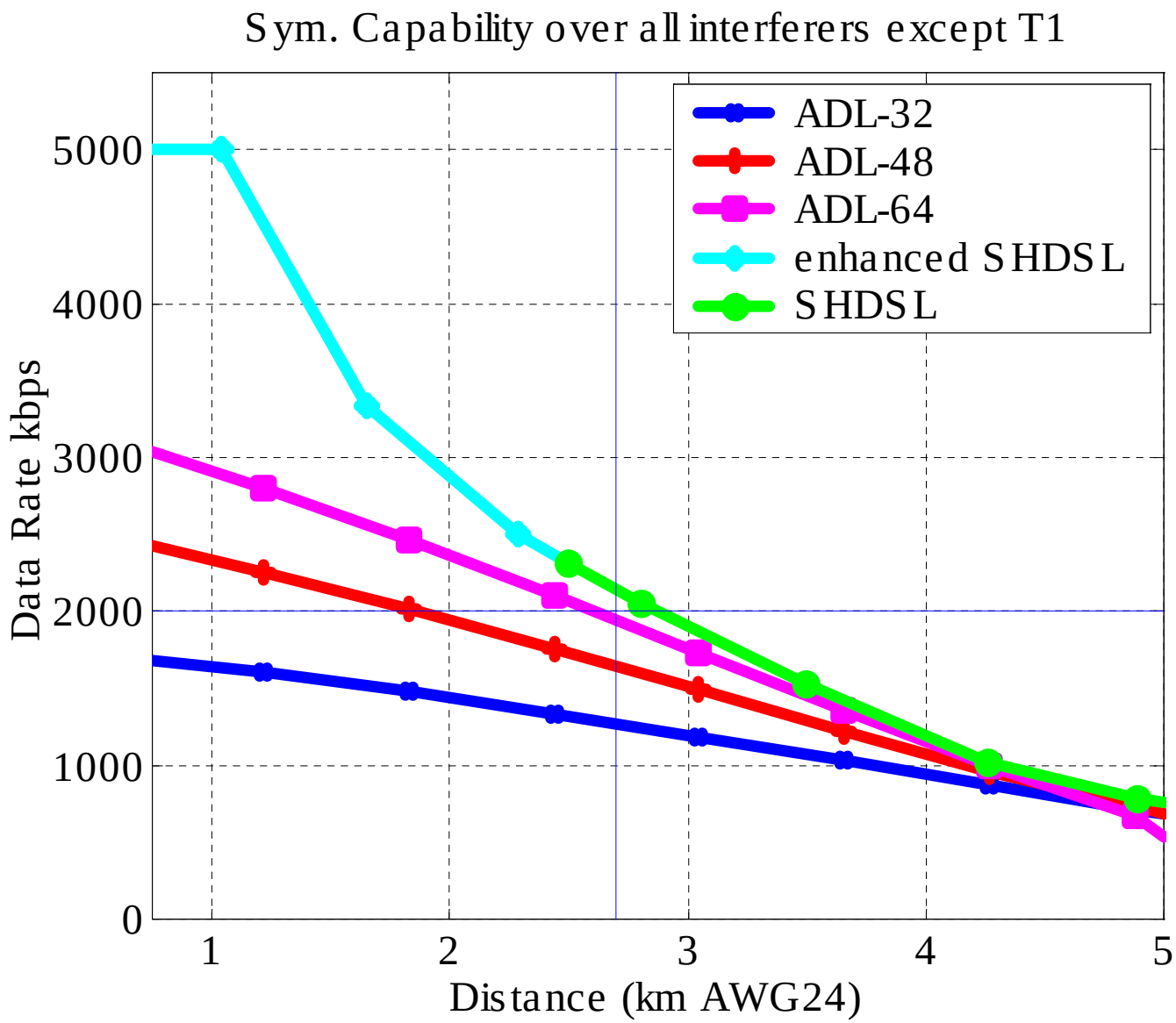
Reality about business loops deployment

- 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, (Broadband business = 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

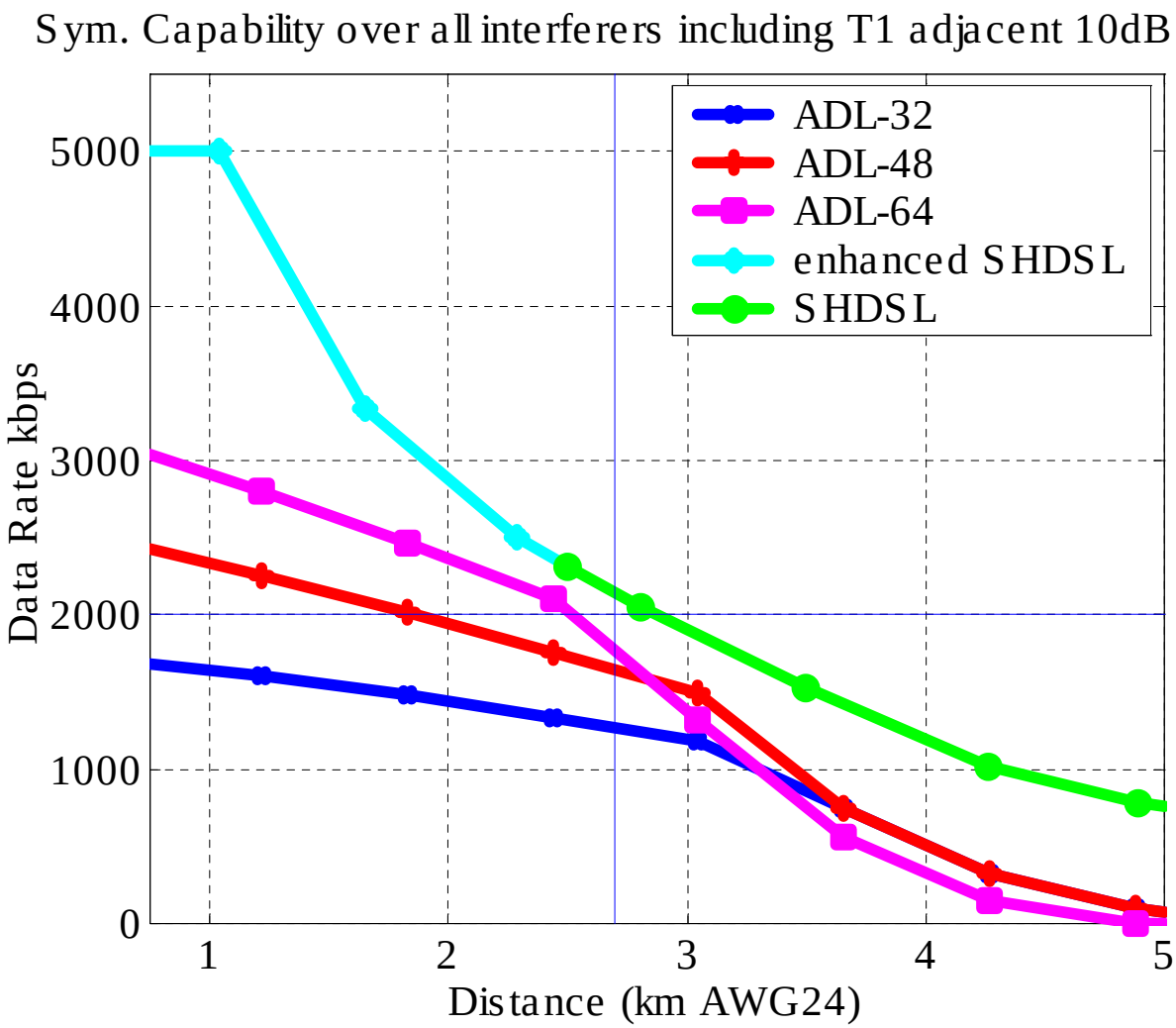
Symmetric capability

- 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 three graphs show the theoretical results. They do not take the efficiency of the modem into account.

All interferers except T1

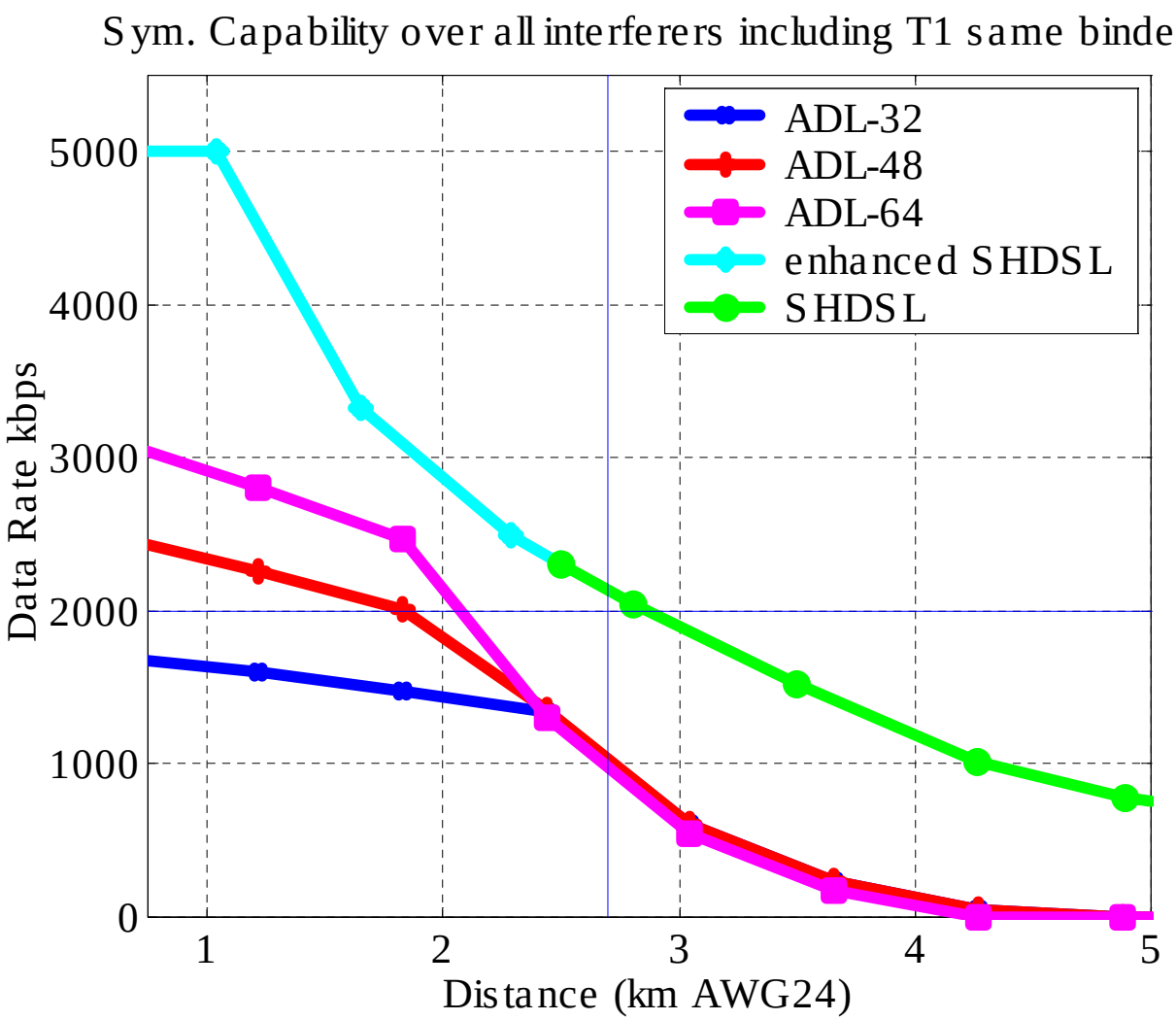


All interferers+ T1 adjacent 10dB



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

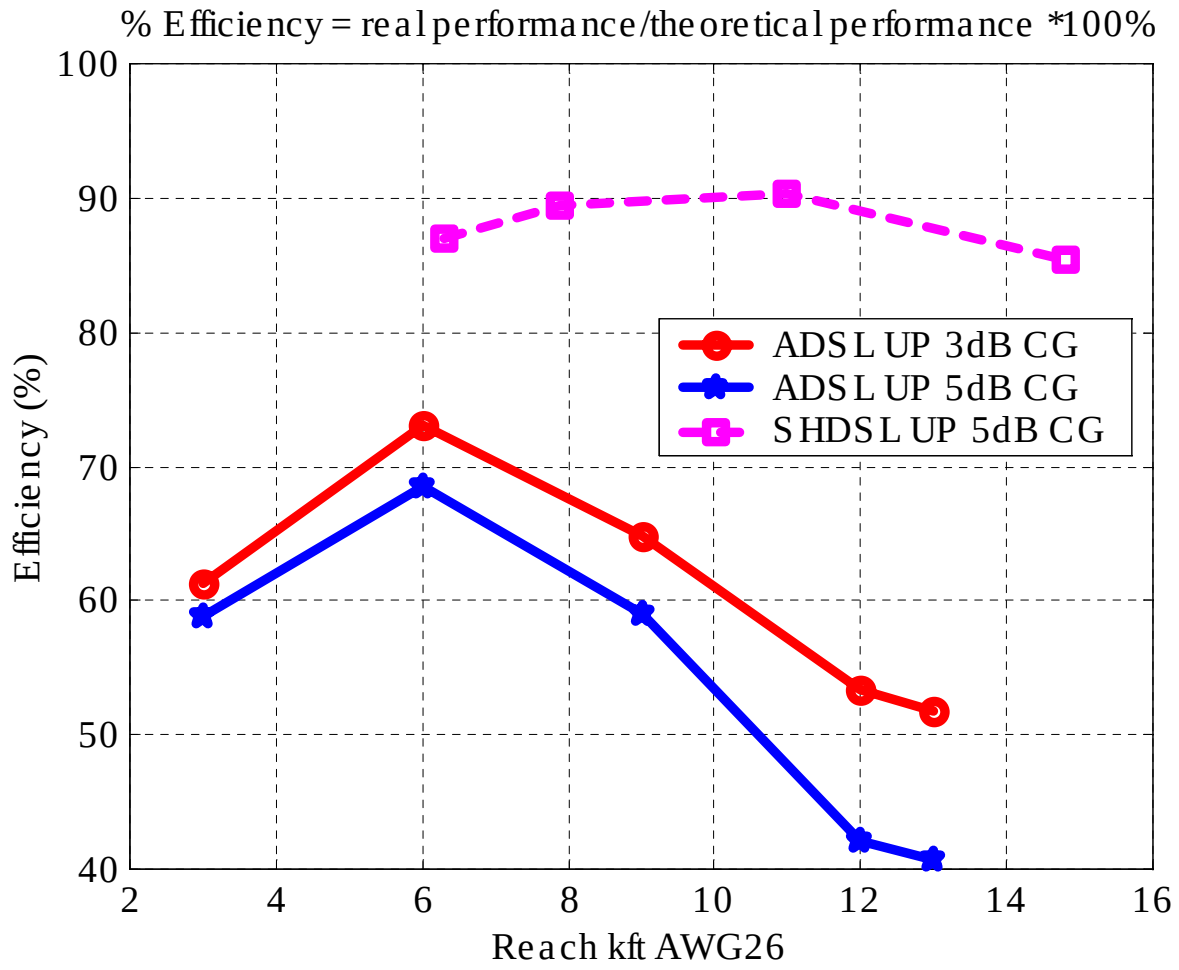
Overall impact of T1 (same binder)



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*

Spectral Compatibility & Deployment

	SHDSL	ADSL2 Annex J	ESHDSL	Annex J & POTS
North America	**Deployed** & Protected	Never Deployed	Never Deployed	Never Deployed
Cont. Europe	**Deployed**	TBD	TBD	TBD
UK	**Deployed**	Not in its present form	TBD	TBD
Far East	**Deployed**	TBD	TBD	TBD
Australia	**Deployed**	TBD	TBD	TBD

Protected: minimum performance is protected.
Never Deployed: obeys SpM document requirements but never deployed
Not in its present form: UK ANFP does not allow annex J PSDs beyond ADL-32, could modify PSDs but would take performance hit
TBD: needs to go through regional regulatory body process

Comparing theory & practice

- In theory, annex J should be able to be deployed everywhere
- In practice, need to go through all the Spectrum management hassle
- SHDSL already included everywhere & protected in some locations
- Case at point: UK : the current definition of annex J is not allowed. One would need to modify annex J and take severe performance hit OR change the UK Spectrum management document.

PAR 5: Economic Feasibility

a) Known cost factors, reliable data.

b) Reasonable cost for performance.

c) Consideration of installation costs.

Does SHDSL satisfy PAR 5?	
5a)	Yes
5b)	Yes
5c)	Yes

Capitalizing on Ethernet traditions

- SHDSL uses a modulation technique familiar to Ethernet
  - ADSL Annex J does not
- SHDSL is optimized for symmetry
  - ADSL Annex J is not
- SHDSL has more predictable performance
  - ADSL Annex J does not

Capitalizing on Ethernet traditions

- **SHDSL is simple**, ADSL is not
  - SHDSL: Single chip, limited PSDs,
    - Plug it in and it works
  - ADSL has many options
    - Annex A, B, I, J chips ?
    - ADSL, ADSL2, ADSL+, ADSL LR chips ?
    - POTS, No POTS systems?
    - FDD , EC, variable split point chips ?
    - LITE ? No LITE ?

Summarizing

Top Ten (plus one)

	Criteria		SHDSL	ADSL2 annex J
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		SHDSL	ADSL2 Annex J
4	Spectral compatibility	Satisfies T1.417 criteria (North America)	✓	✓
		Basis System of T1.417 (i.e. protected)	✓	✗
		Satisfies UK ANFP	✓	✗
5	Standards	ITU standard	✓	✓
		ETSI Standard	✓	(informative annex)
		ANSI standard	✓	✗
6	Telco operator support		✓	?

Top Ten (plus one) (ctnd)

	Criteria		SHDSL	ADSL2 Annex J
7	Cost		Similar	
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		SHDSL	ADSL2 Annex J
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. 12/05/02: point 11 was written in September. Today, we are in a line code war, we are slowing down other standards, we are slowing down the Optics tracks. It's time to move on ! Let's decide.				

Conclusions

- Both SHDSL & ADSL are great systems conceived for different purposes
- SHDSL has superior symmetric capabilities both in theory & practice
- SHDSL has consistent performance across a large number of interferers
- Spectral compatibility: SHDSL already accounted for, annex J not

Why SHDSL ?

- Deployment of EFM PHYs will be governed by Telco operators
- Telco operators have shown preference for SHDSL for long reach
- Cannot ignore business segment for a successful standard (look at history)

Additional slides
(if you haven't had enough)

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.

Status of the various technologies

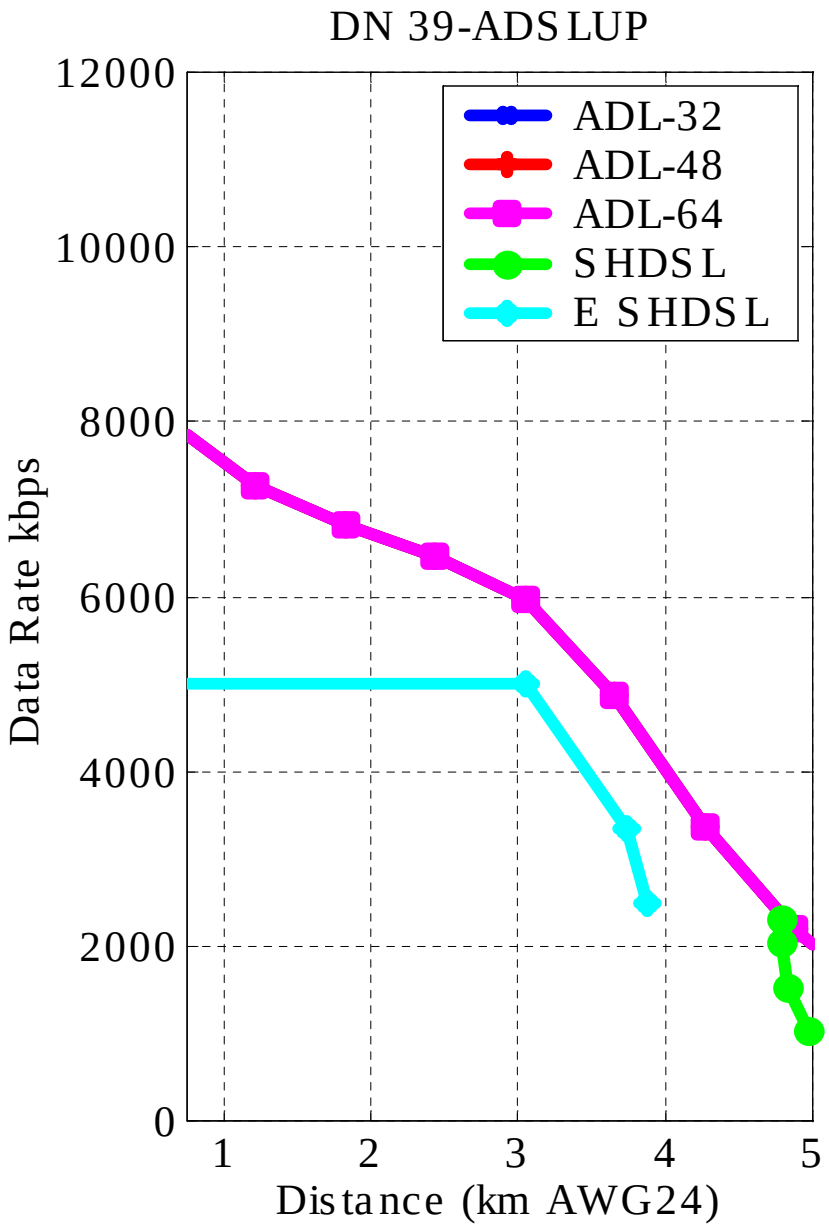
SHDSL: ITU standard since Feb. 2001

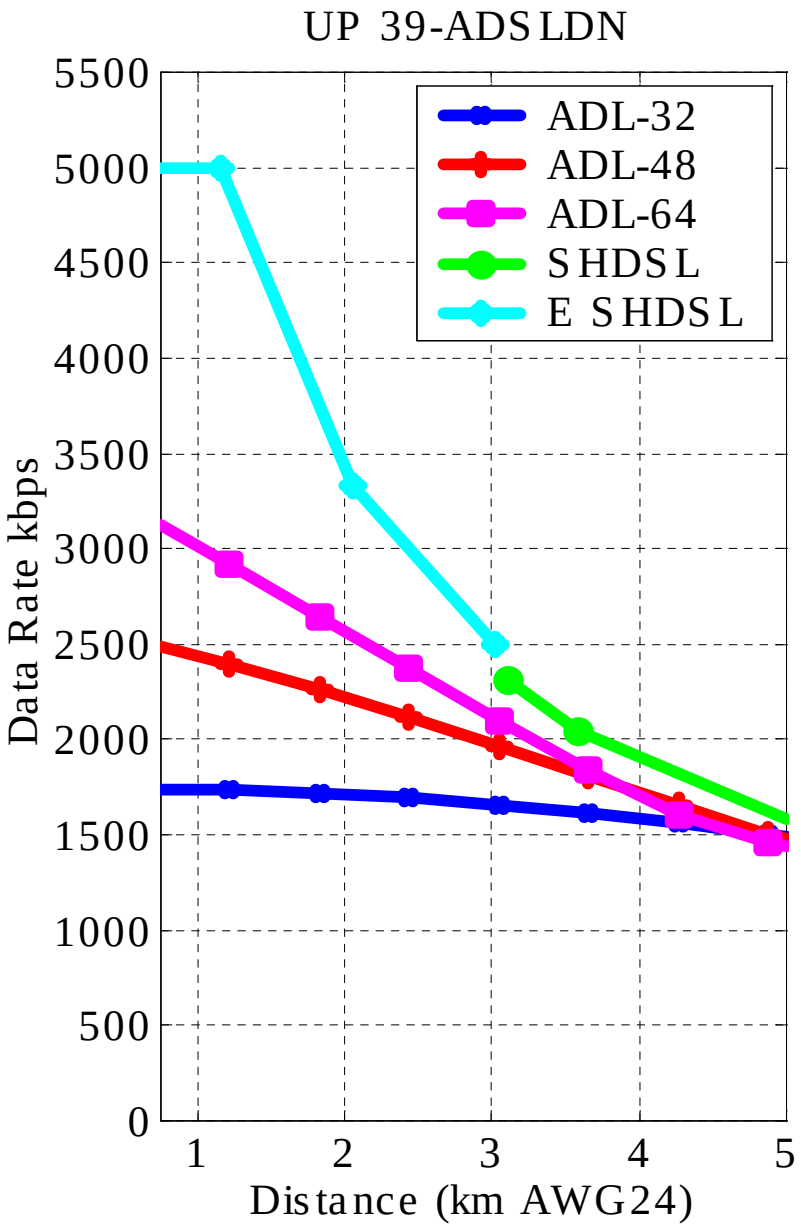
Enhanced SHDSL: part of the bis version of SHDSL and discussed within ITU. Not a standard yet.. Constellations and spectral masks are being discussed. Proposals range from no changes to existing PSDs to roughly doubling the bandwidth of existing SHDSL. At a minimum, by keeping the same spectral mask as the approved SHDSL PSDs, enhanced SHDSL can achieve 3 Mbps with TC-32-PAM, at a maximum it can achieve 5.7Mbps with TC-32-PAM. Therefore, on the performance graphs, depending on the final state of the enhanced SHDSL allowed PSDs, performance can be roughly lower bounded by the 3Mbps line and upper-bounded by the 5Mbps line.

ADSL2 annex J : part of ADSL2, an ITU standard since May 2002

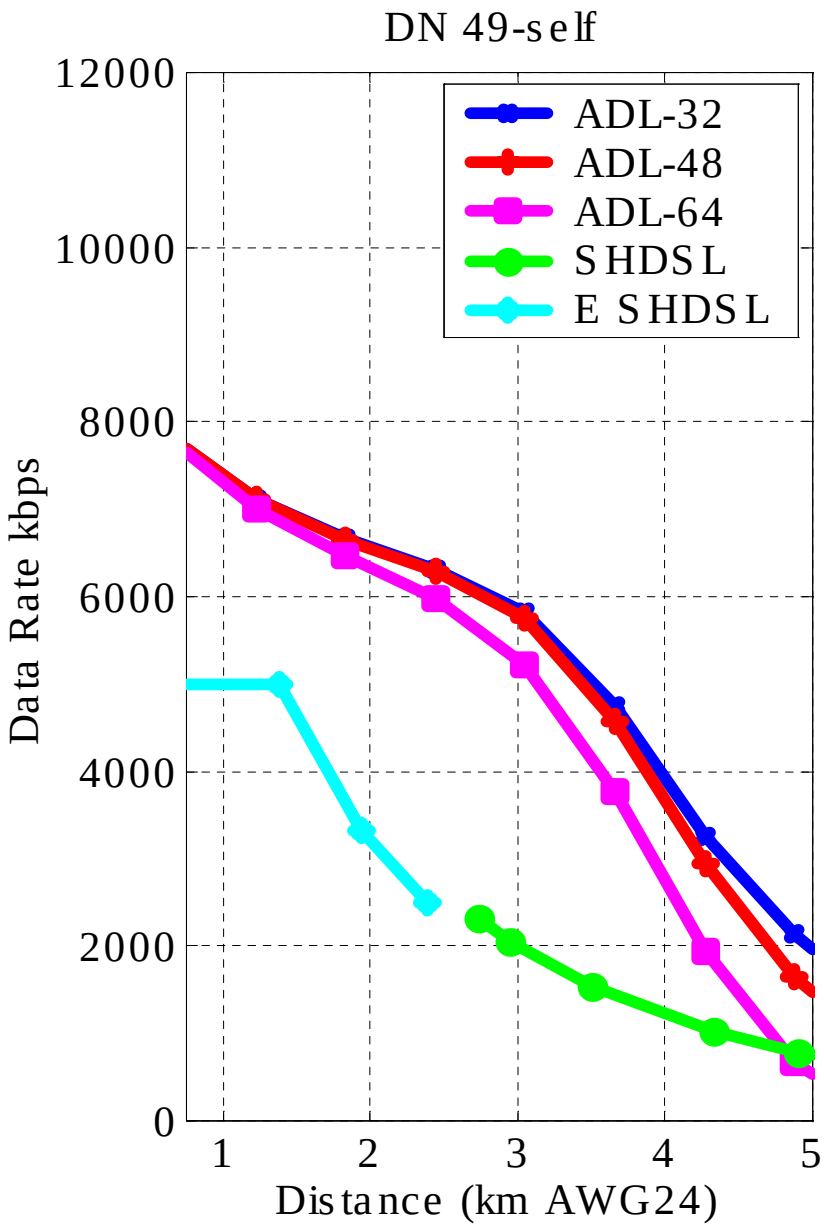
ADSL+ annex J over POTS: proposed as part of ADSL+ and discussed within ITU. Not a standard yet.

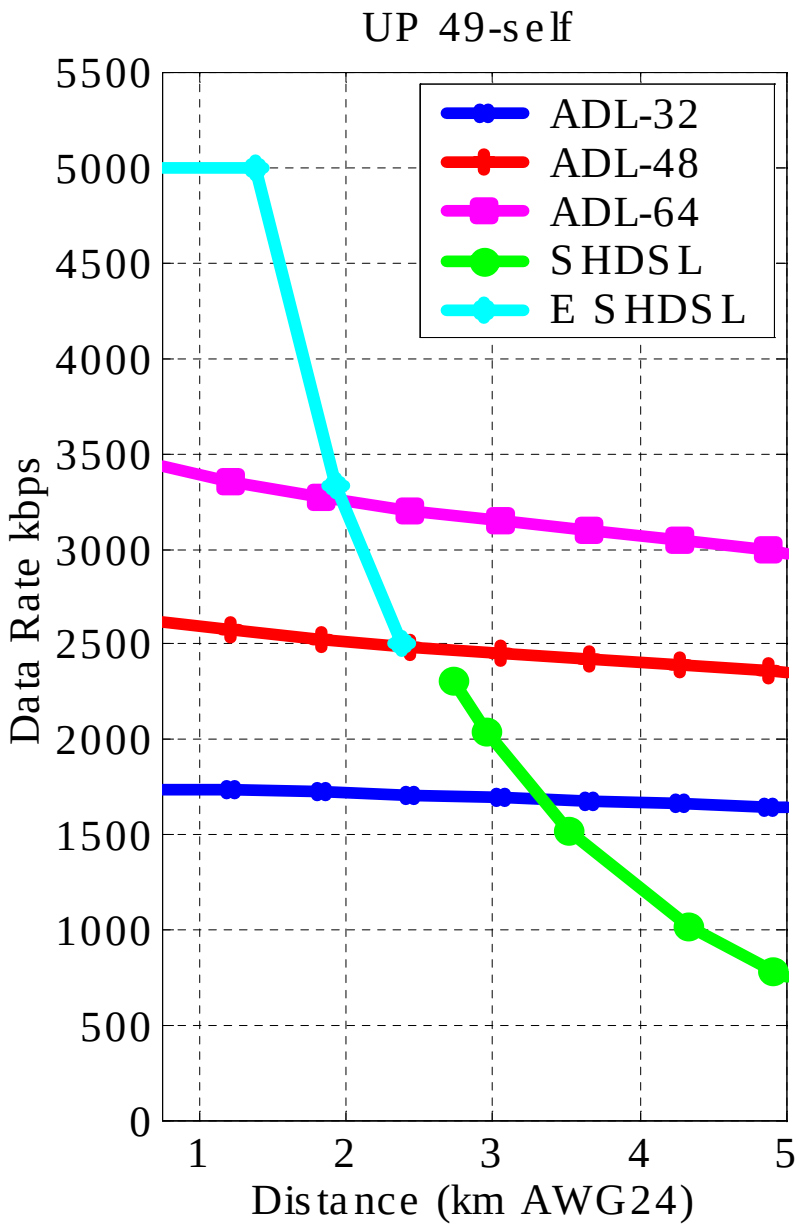
Sample Results: 39-ADSL



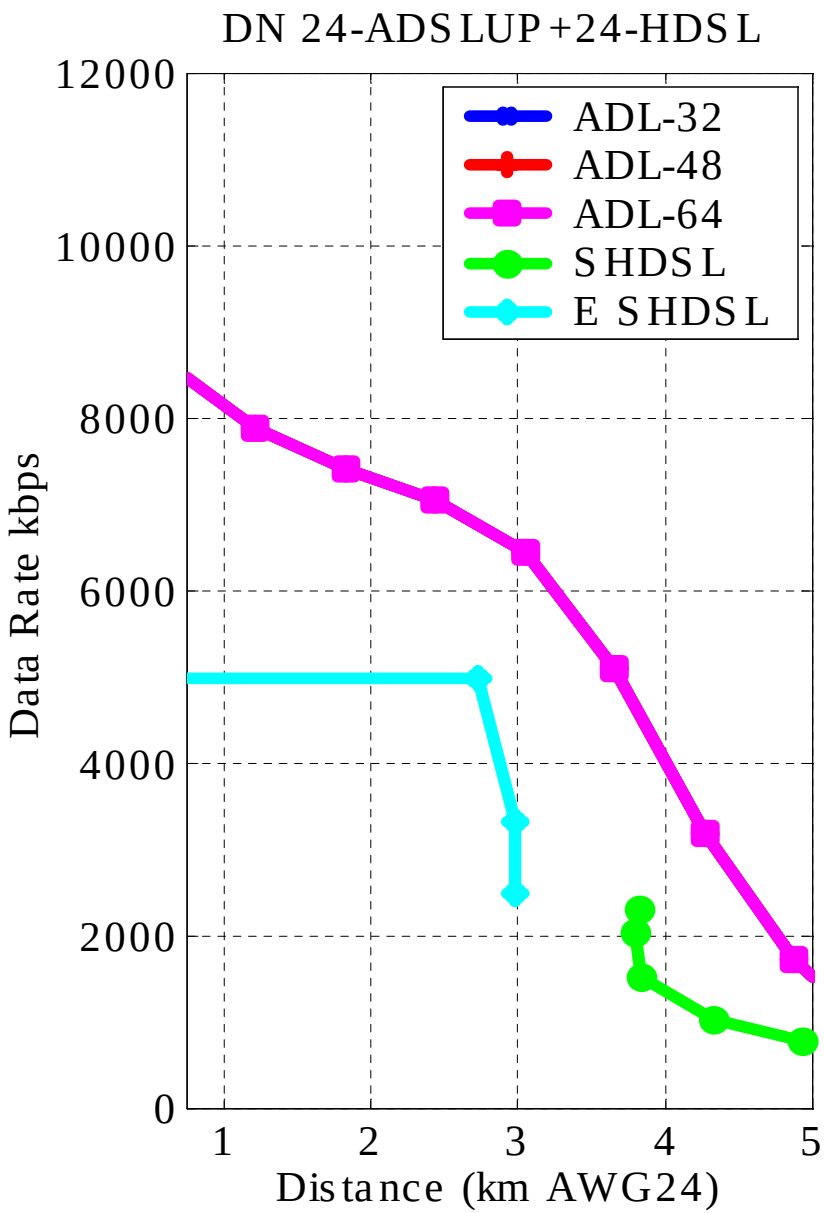


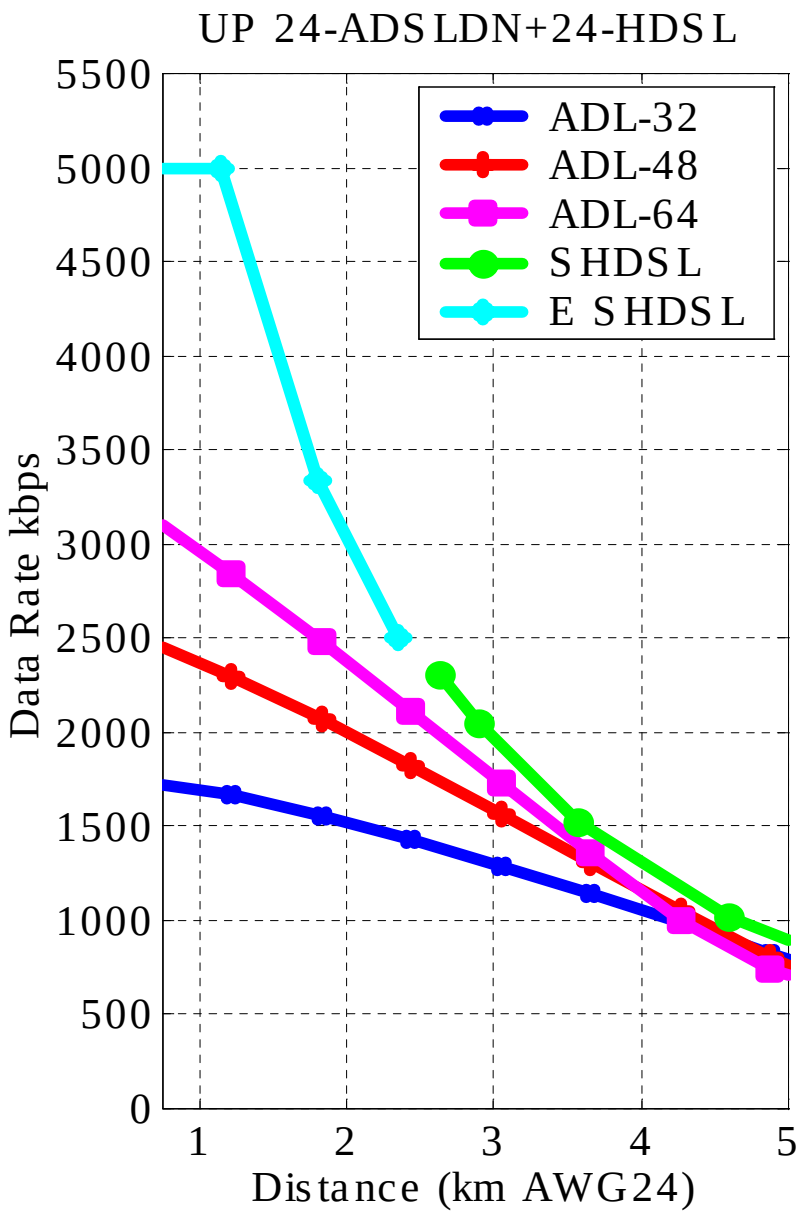
Sample Results: 49-self





Sample Results: 24-ADSL + 24 HDSL

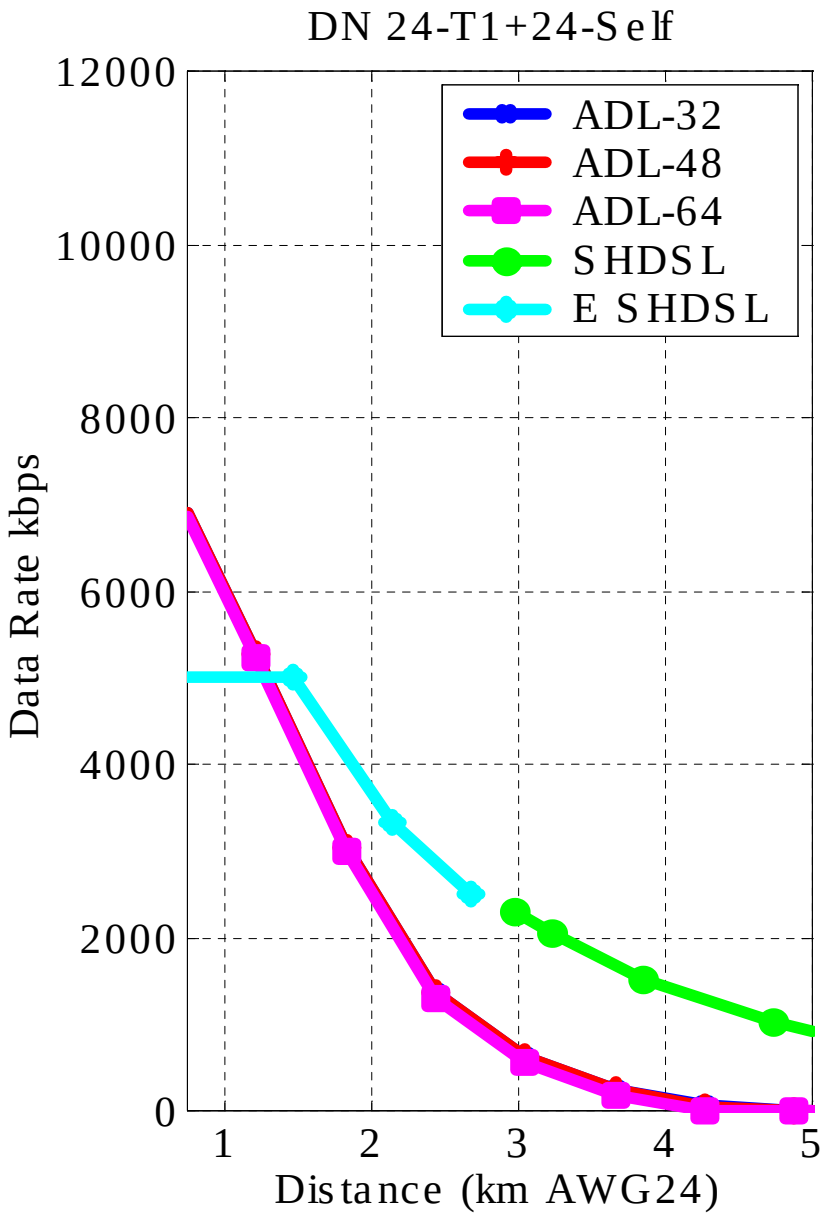


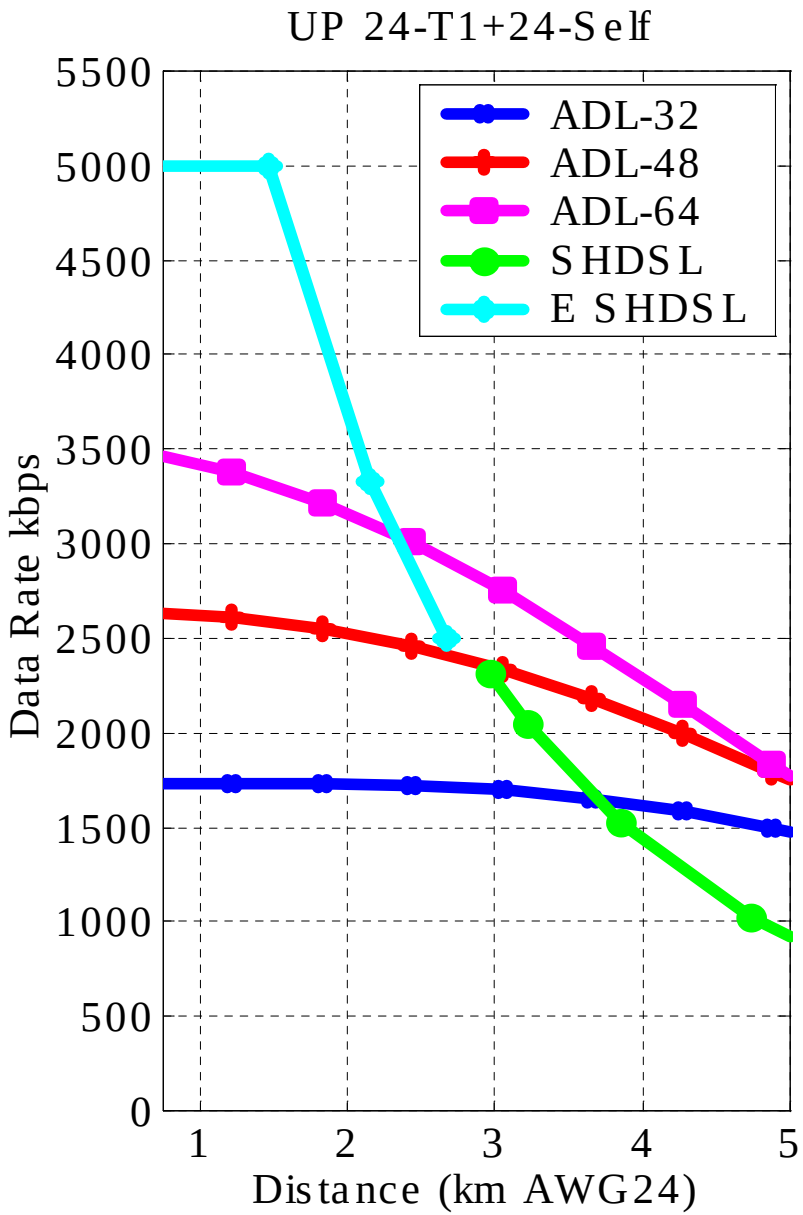


T1, the secret FDD system killer

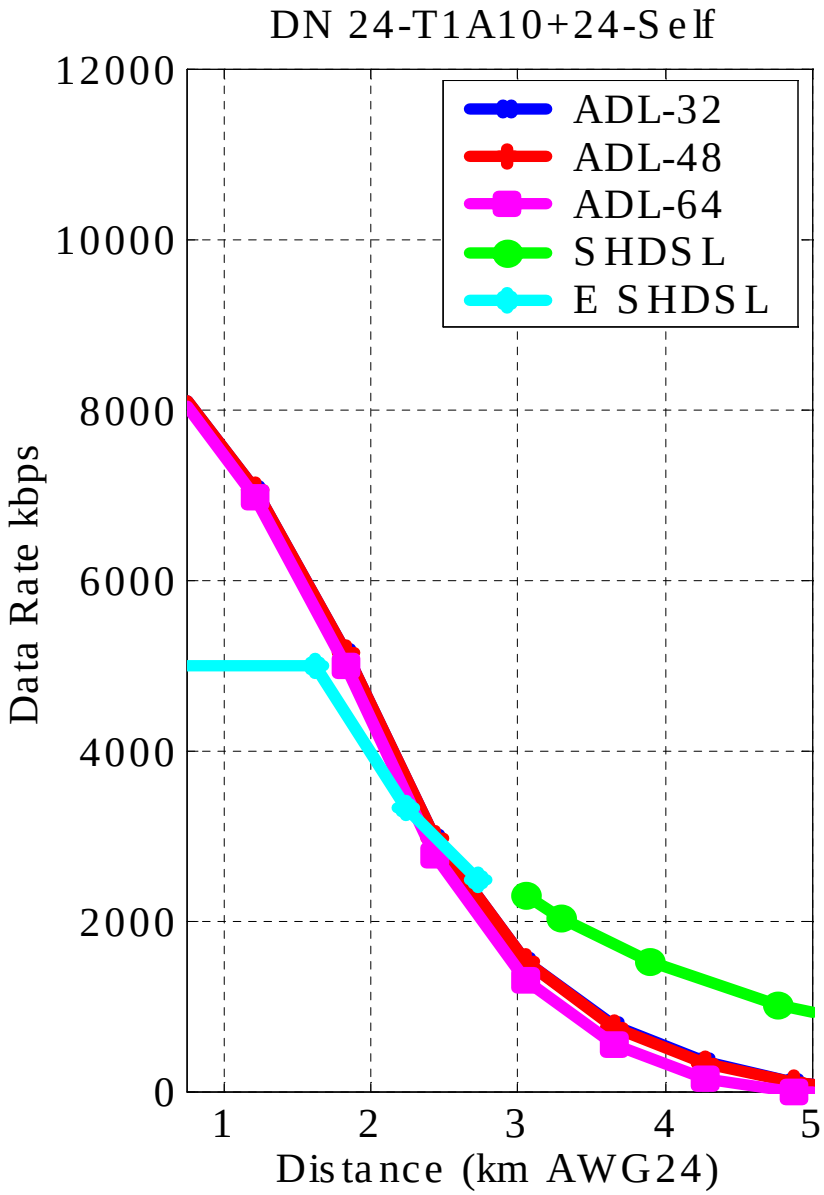
- 3 level of interference
  - Same binder
    - 0dB attenuation (used for SHDSL)
  - Different binder and CPE separation
    - 15.5dB attenuation (used for ADSL)
  - Different binder
    - 10dB attenuation (regular assumption)

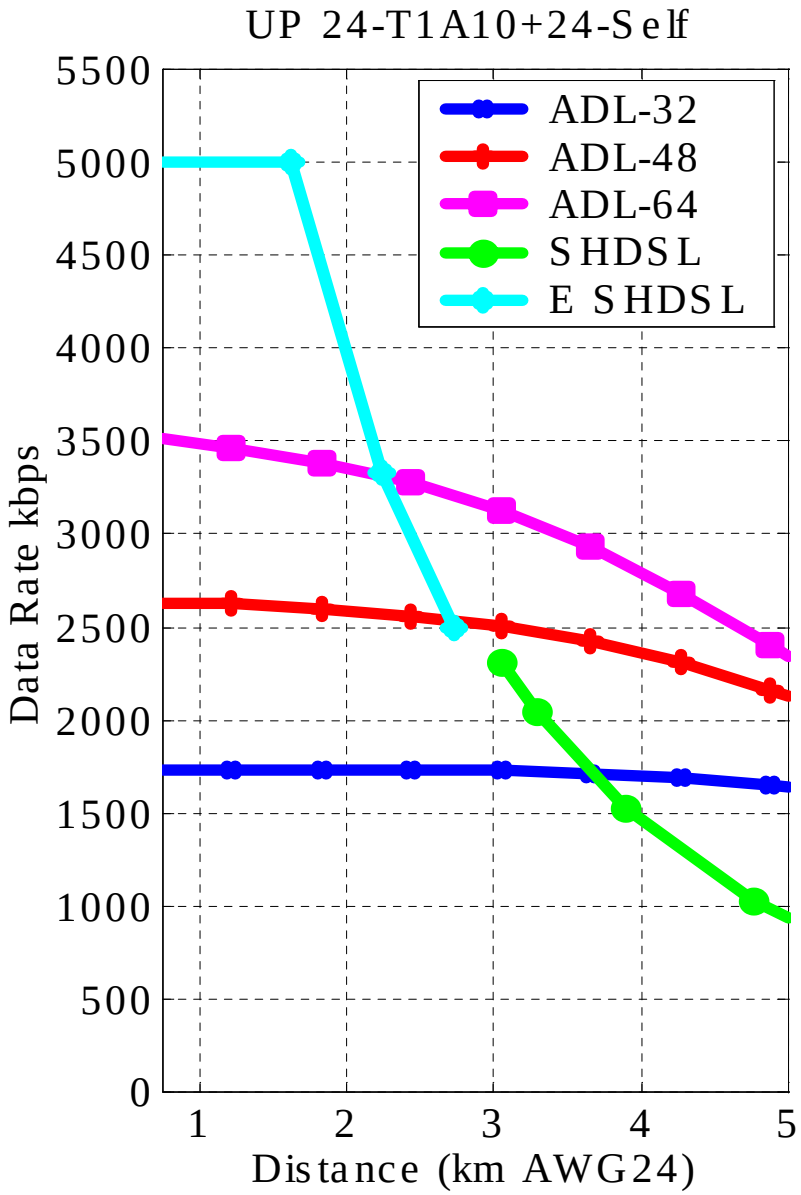
Sample Result:T1-same binder



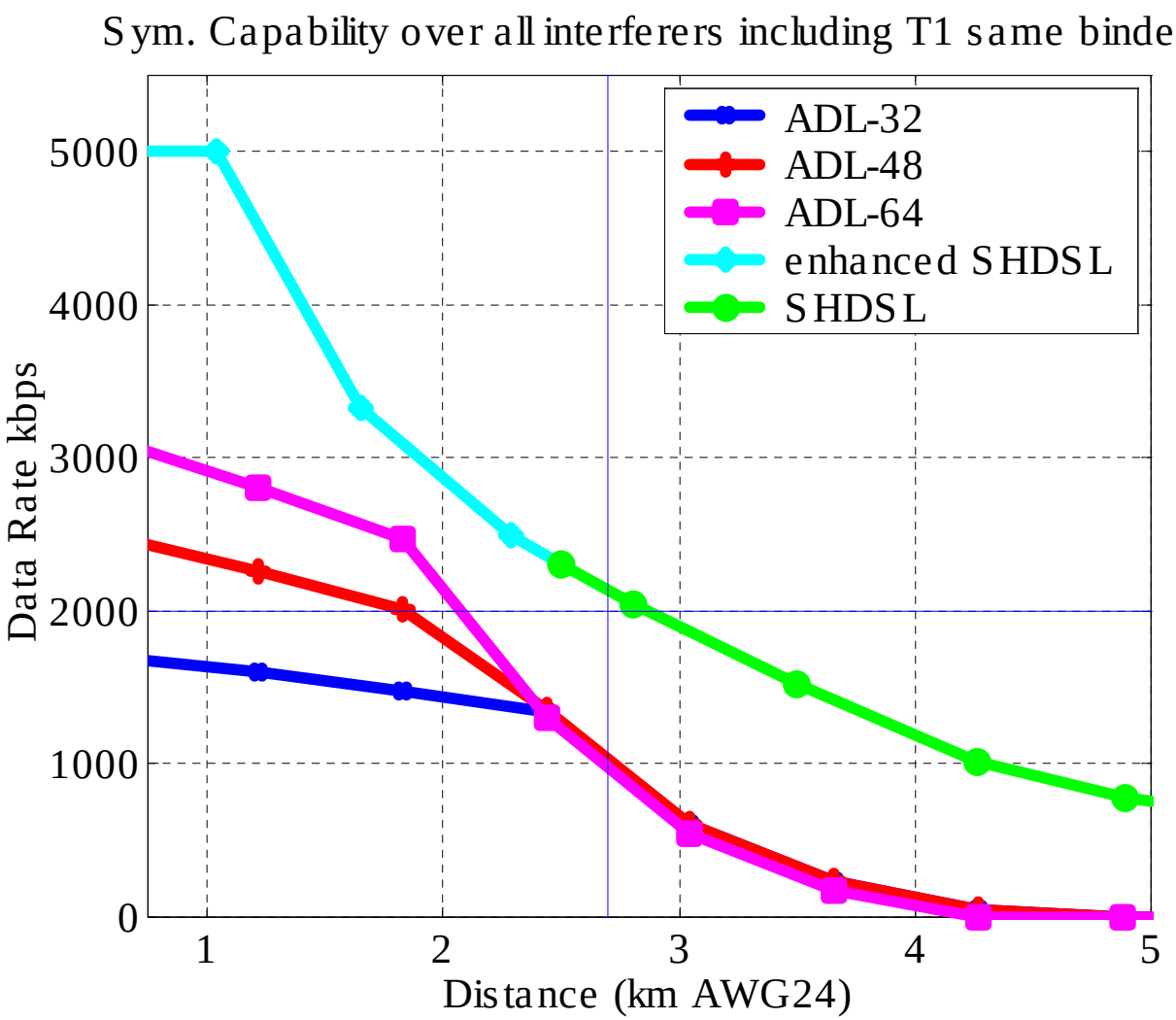


Sample Result: T1-adjacent binder(10dB)

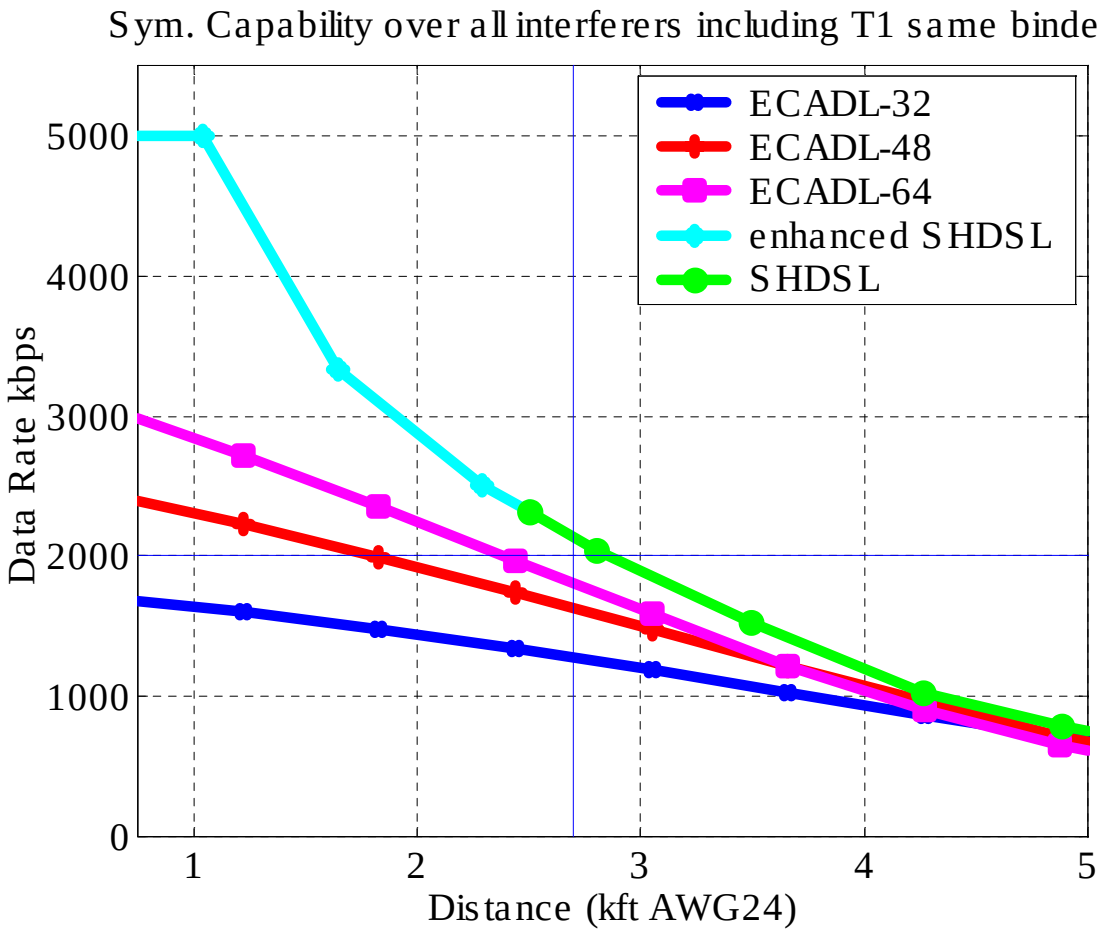




Overall impact of T1 (same binder)



Overall impact of T1 (same binder) (Assuming Echo cancelled Annex J)



Echo cancellation improves performance for annex J but still does not outperform SHDSL. The graph shows the results for a full overlap EC annex J. Other UP/DN split points for annex J will not outperform SHDSL either.

“Myths” & realities

- SHDSL is a symmetric only system: **WRONG**
  - SHDSL standard specifies UP & DN rates independently
- SHDSL cannot gain from MIMO (Multiple Input Multiple Output) or cross-talk cancellation: **WRONG**
  - MIMO and cross-talk gains can be applied to SHDSL
- For long reach, PAM is a less efficient line code than DMT: **WRONG**
  - Look at performance & efficiency section.

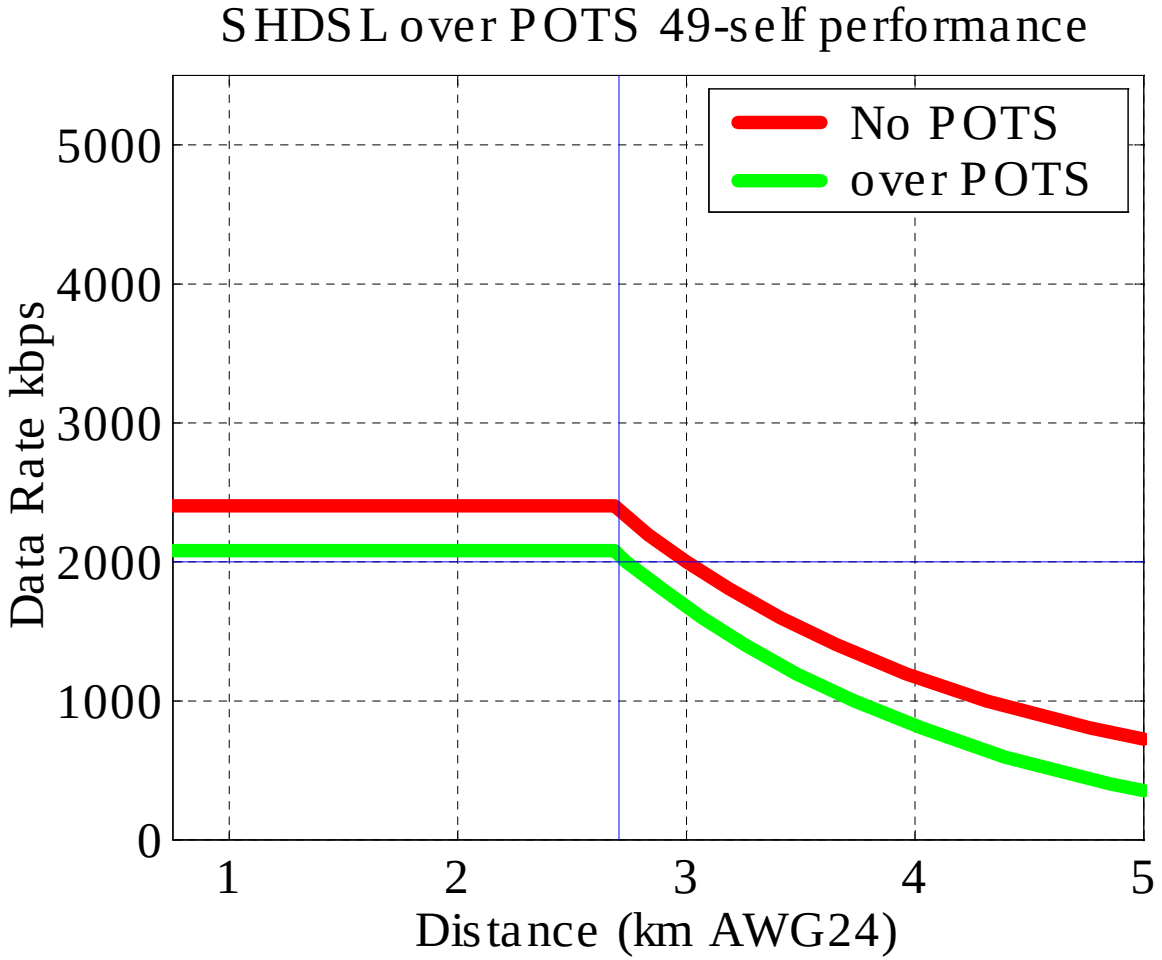
"Myths" & realities

- SHDSL cannot run over POTS using splitters: **WRONG**
  - Use spectral shaping and regular POTS splitters (see performance section)
  - Requires modifications to SHDSL just as POTS support requires modifications to Annex J
- Choices were made when SHDSL was designed to optimize it for symmetric rate delivery & robustness: **TRUE**
  - That's a good thing, not a limiting thing
- Other options can be implemented: **TRUE**

Spectral compatibility & residential market?

- **Both** Annex J and SHDSL have an impact on already deployed "regular" ADSL over POTS
  - Each can have more impact than the other under certain conditions
- **Neither** supports POTS in current standards
- **Best** residential solution is "regular" ADSL
  - Already covered and deployed to many millions of customers using ATM – no screaming need for change
  - Does not meet Ethernet long-reach objectives

SHDSL over POTS



Use "regular" splitter to separate voice from data

TC-16PAM/8th order Butterworth/f3dB 40kHz/5dB Margin

Use VDSL rather than ADSL if asymmetric delivery is needed

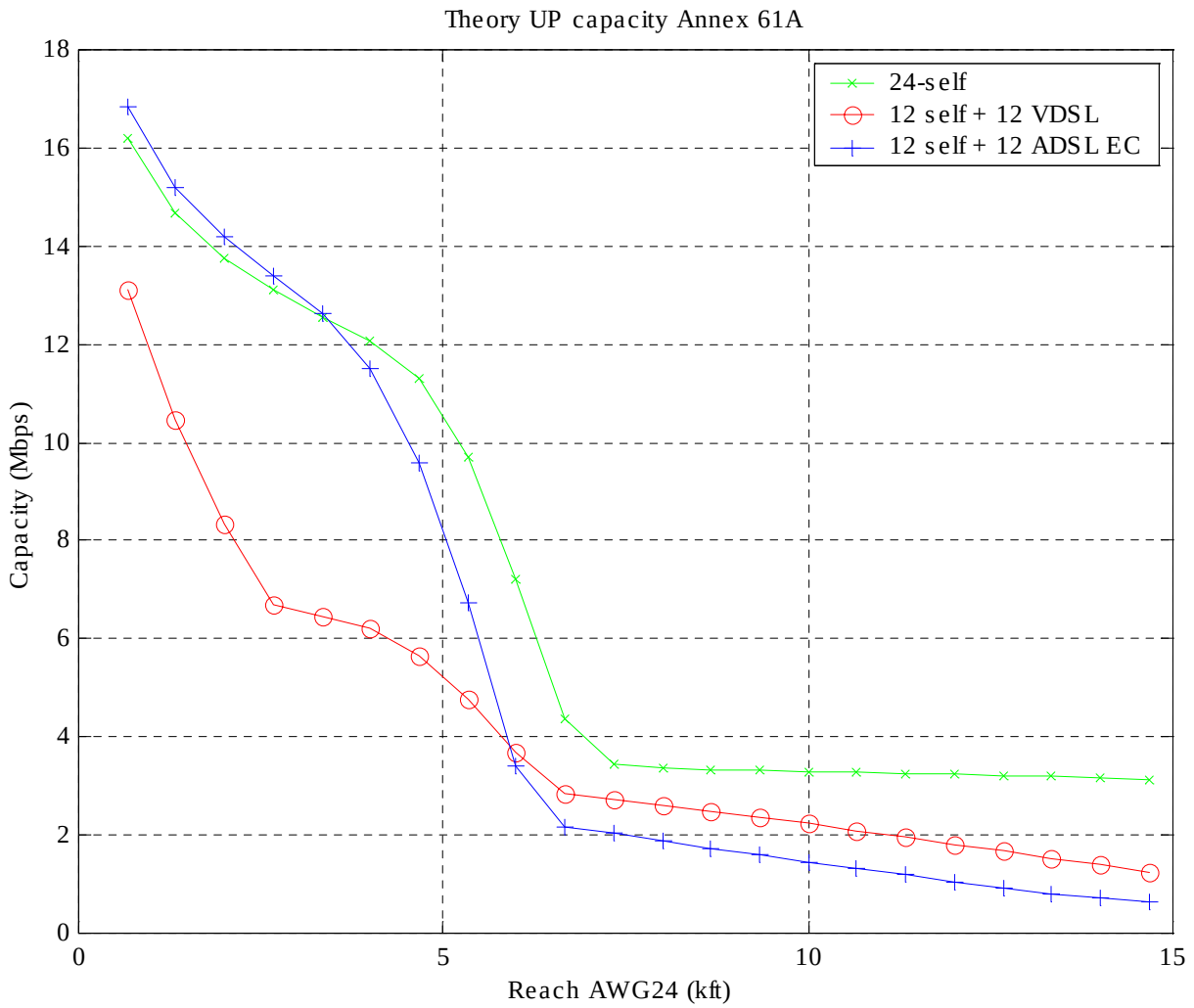
- If the end game is to have VDSL everywhere and a minimum of PHYs
- VDSL includes asymmetric capability of ADSL (with upstream 0).
- Various ideas have been juggled for VDSL LR based on other spectra. Look at annex 61A

- 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 62A 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 62A



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

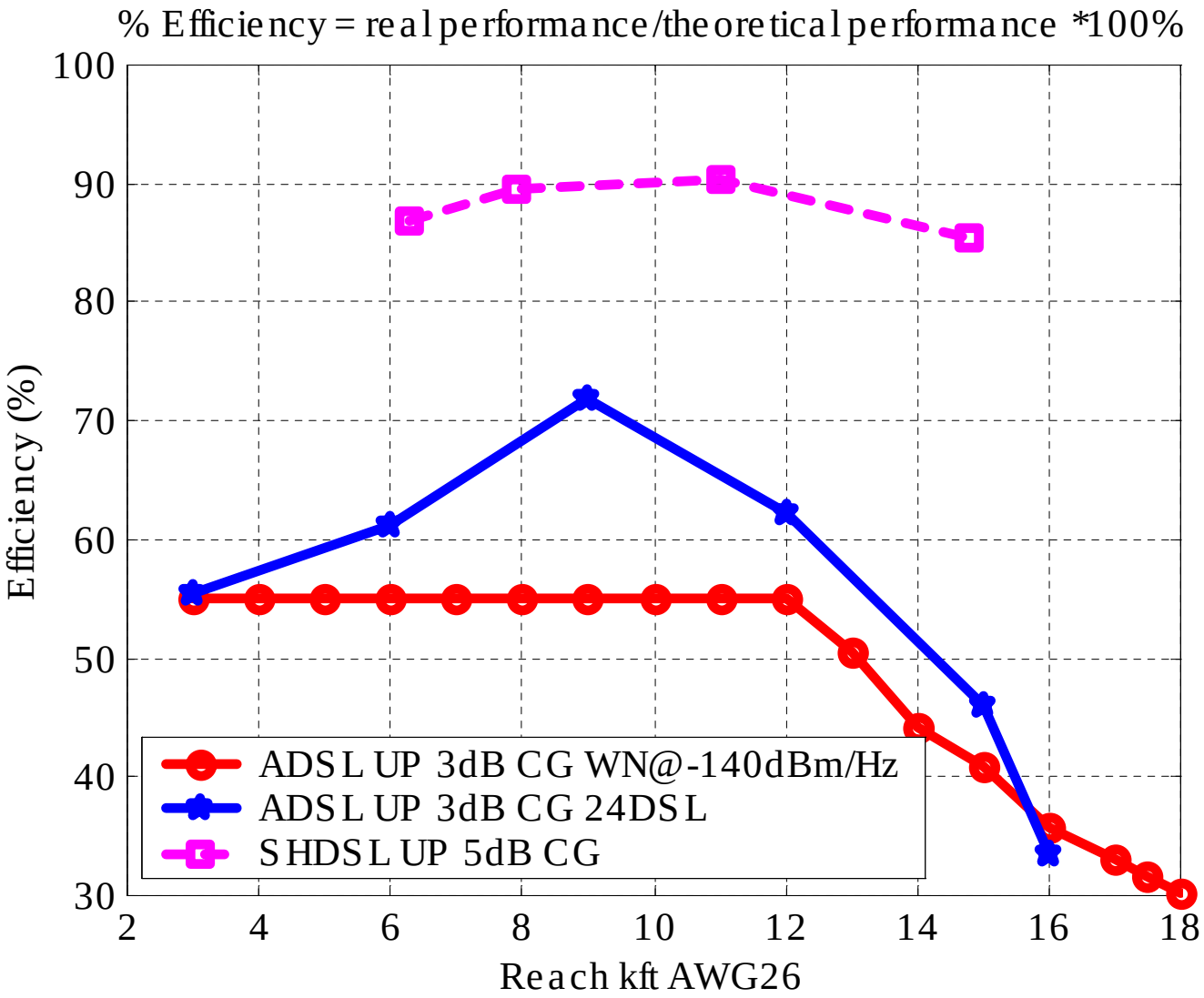
We compute the theoretical performance assuming the regular set of assumptions. Margin is 5dB, Noise floor –140dBm/Hz.

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%

TR48 with No Noise or ISDN



FCC numbers Business & Institutions

• ALL	• Only > 200kbps both directions
• ADSL 11% • Other wireline 53% • Cable 10% • Fiber 25% • Wireless 1%	• ADSL 5% • Other wireline 56% • Cable 11% • Fiber 27% • Wireless 1%

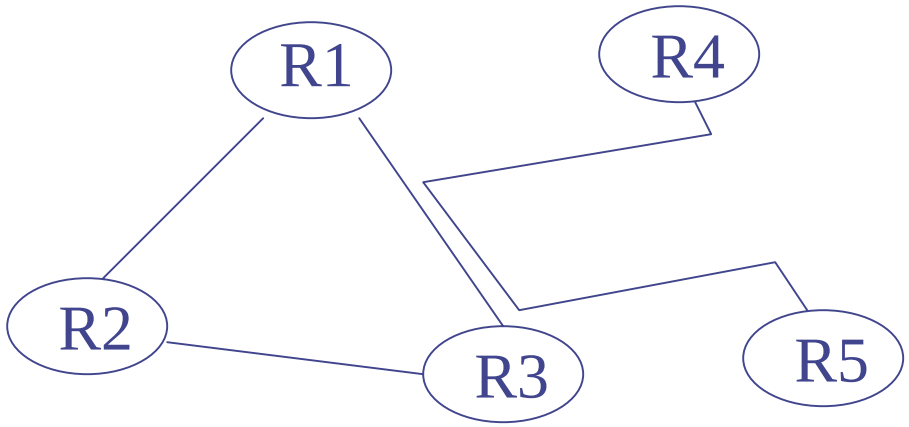
FCC numbers Residential & S Business

• ALL	• Only > 200kbps both directions
• ADSL 32% • Other wireline 2% • Cable 64% • Fiber 0% • Wireless 2%	• ADSL 21% • Other wireline 3% • Cable 74% • Fiber 0% • Wireless 1%

Table 1 versus Table 3

- Page 4 / 1st bullet
- Reporting entities estimate the percentage of their high-speed lines in service that connect to residential and small business end-users customers (as opposed to connecting to medium and large business, institutional, or government end-user customers). …

Ethernet Architecture



- Rx => Router/Switch location
- If use asymmetric PSDs, where is upstream and downstream ?
- If connect R4/R5 "backwards", kill performance of both R4/R5 and R1/R3 link
- Symmetric PSDs are "idiot proof"

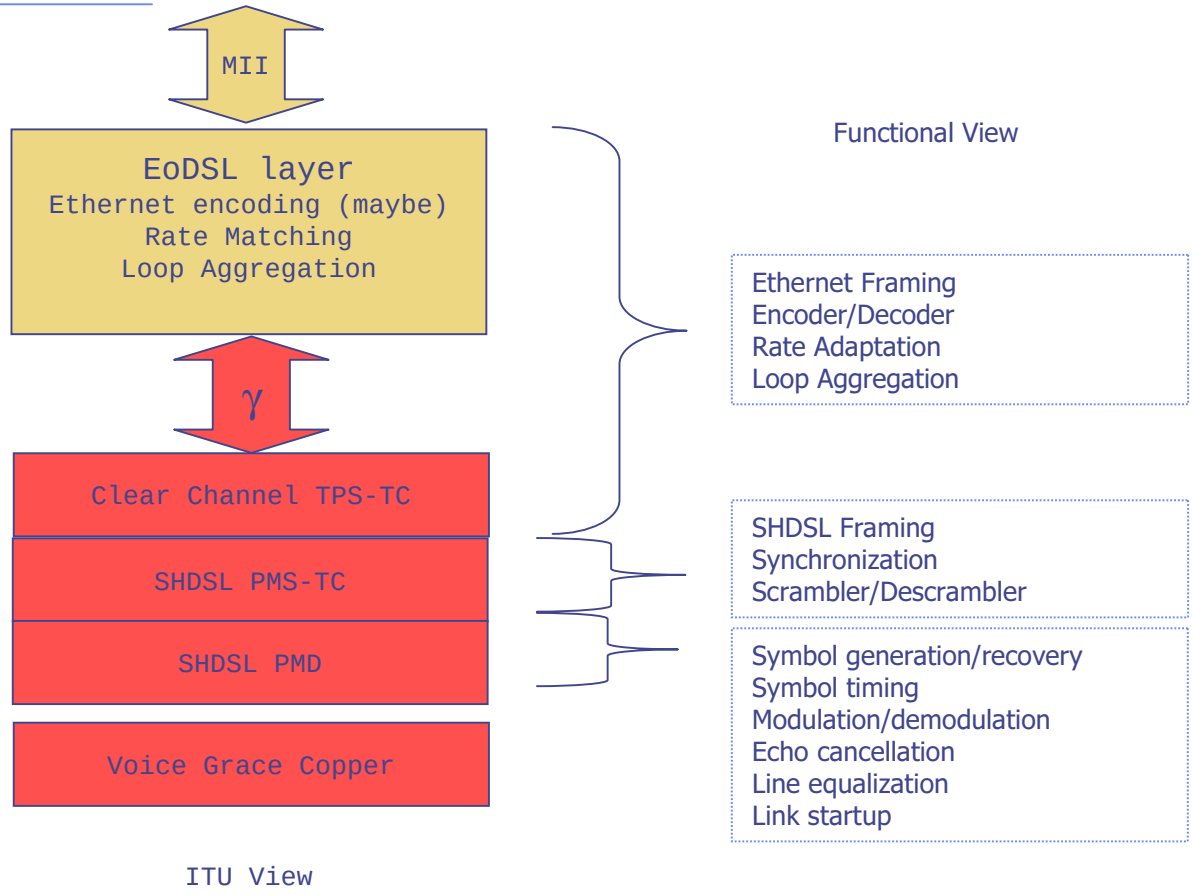
Baseline Reference Model

Interfaces and Architecture

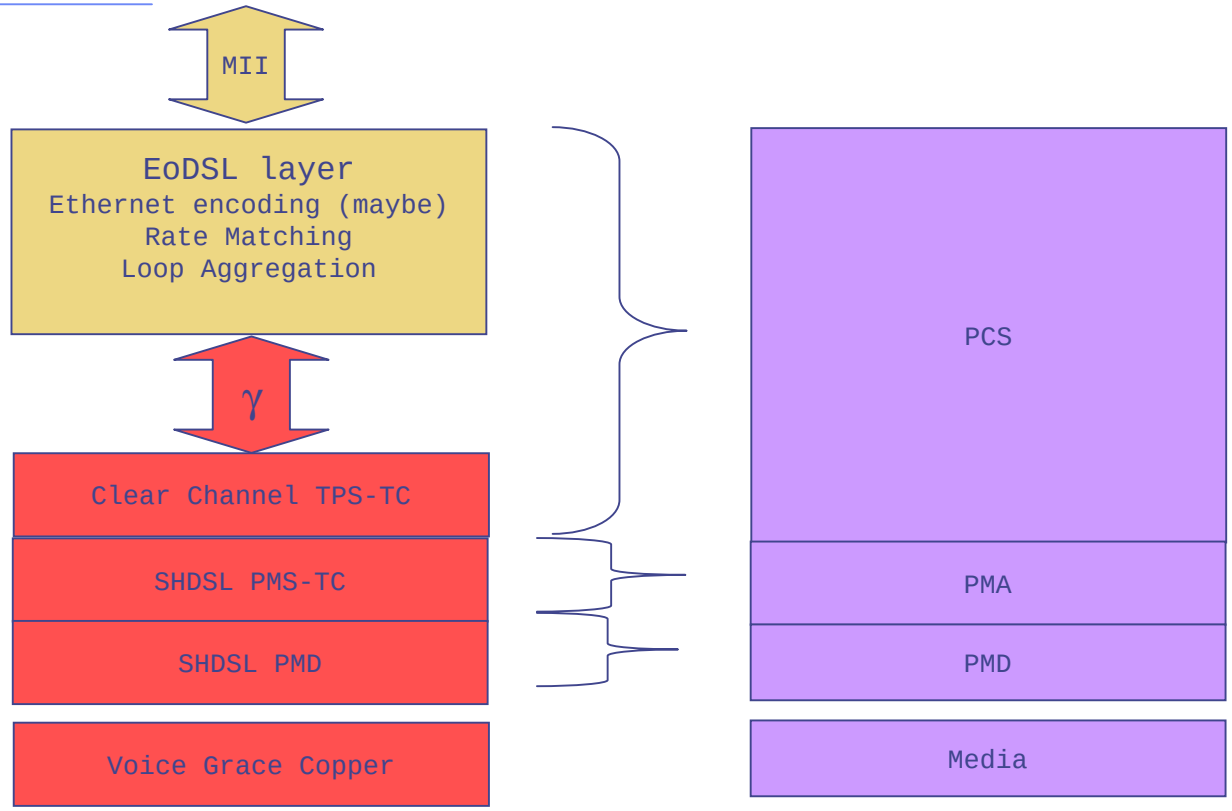
Principles and Strategy

- Require little or no changes to existing standards
  - IEEE
  - ITU
  - ANSI
- Try to keep changes below MAC and above gamma interface
- Specify interfaces and new functionality only (reference rather than duplicate)

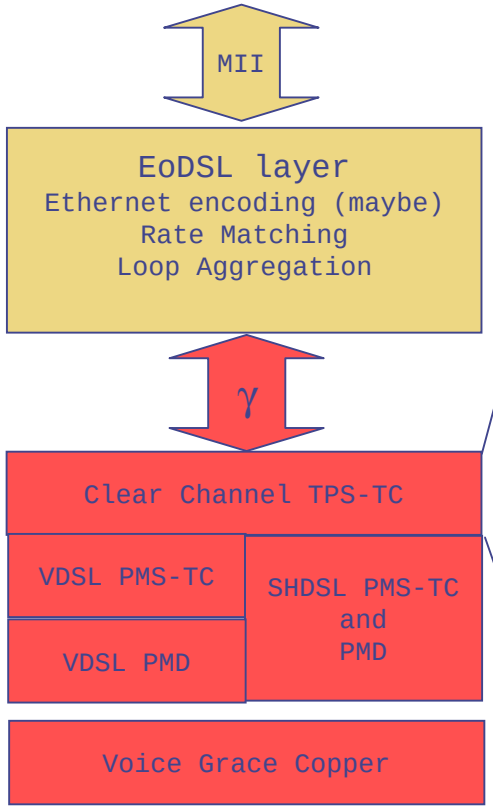
Interfaces and Architecture



Interfaces and Architecture



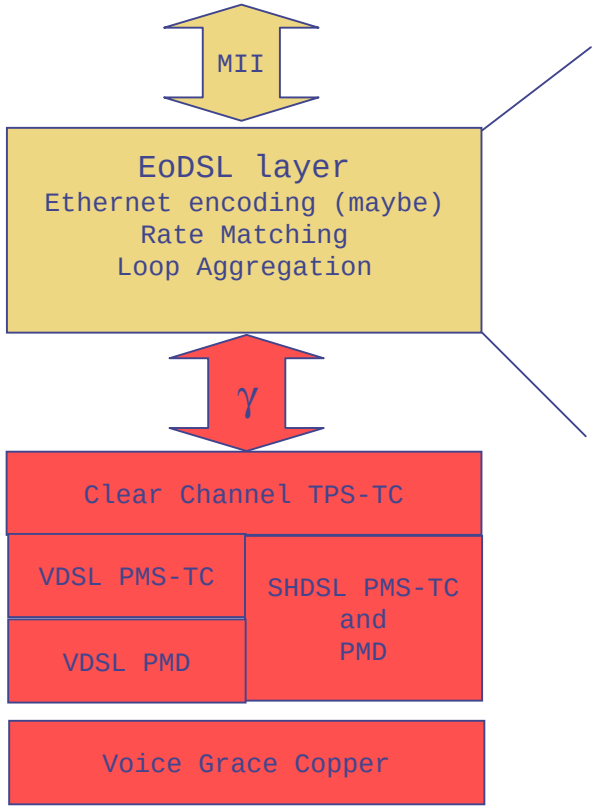
Interfaces and Architecture



Items in RED defined in ITU/ANSI standards
- VDSL (G.993.1) has defined PMS-TC and PMD
- SHDSL (G.991.2) has defined PMS-TC and PMD
- VDSL defines PTM-TC for packet transfer mode
    - Packet interface
    - HDLC byte stuffing
    - HDLC framing
    - HDLC CRC
- Clear channel TPS-TC defined in G.991.2
    - Very simple bit-transfer interface
    - **Not** defined in G.993.1 (VDSL)
    - Provides maximal flexibility to EoDSL layer (bit-pump)
- Decision on HDLC vs 66/64 is independent of TPS-TC
- Decision on loop aggregation is independent of TPS-TC
- Issues: Where does framing and encoding happen? How is it done?

Need a consistent interface (clear channel vs PTM-TC) for all PHYs.

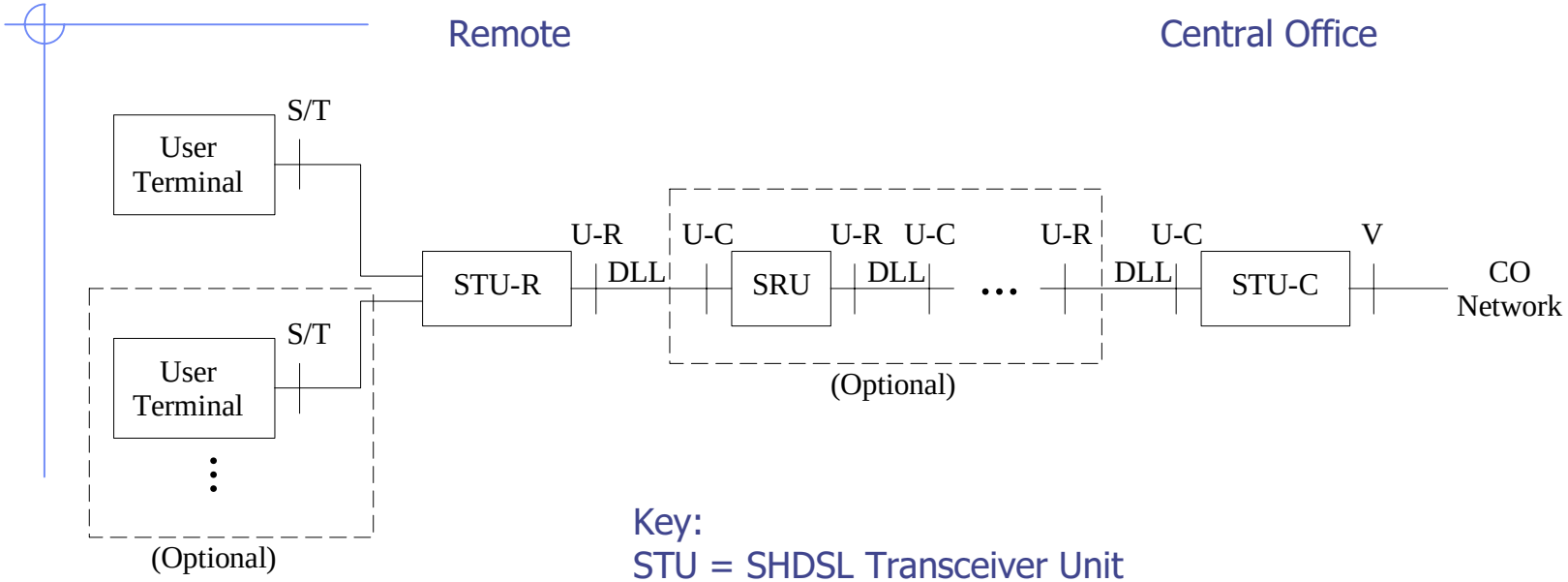
Interfaces and Architecture



- Loop Aggregation.
  - Covered in fosmark_1_0302.pdf.
- Rate Matching.
  - Covered in marris_1_0302.pdf.
- Framing and Encoding.
  - Covered in many other proposals. Using clear channel TPS-TC does not restrict us to HDLC framing and byte stuffing.

All functions happen above bit pump interface to clear channel TPS-TC

Reference Model



Key:
STU = SHDSL Transceiver Unit
SRU = SHDSL Regenerator Unit
STU-C = STU Central Office
STU-R = STU Remote
U = Loop Interface
U-C = U Central Office
U-R = U Remote
DLL = Digital Local Line
(Blatantly stolen from G.991.2)

Things to finish…

- Management (MIB, profiles)
  - Requires mapping to SHDSL PMD MIB
  - Profile use same as VDSL
  - EOC parallel for VDSL/SHDSL
- Management interface
  - Need details – need consistency across all EFM PHYs
- Must not operate in 4-wire mode
  - Use 802.3ah loop aggregation instead
- Hooks into G.994.1 for Ethernet handshaking
  - Scott's protocol addressing this
- Link carrier detect after successful completion of xDSL link initialization(?)