DMT - based XDSL: The On-Ramp to the Information Superhighway

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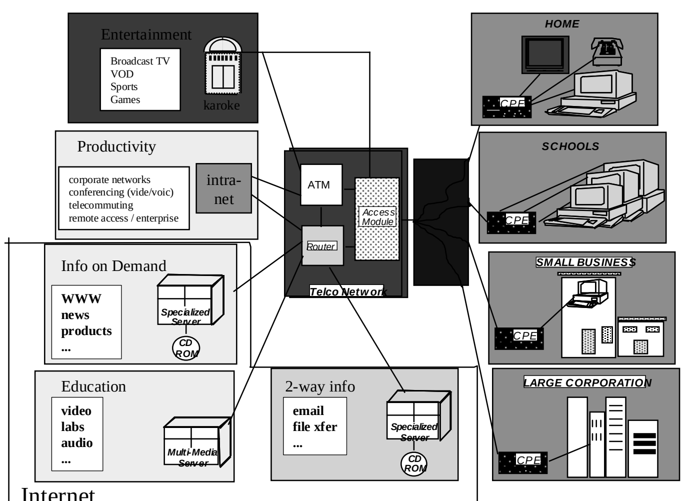
New Revenue for Service Providers

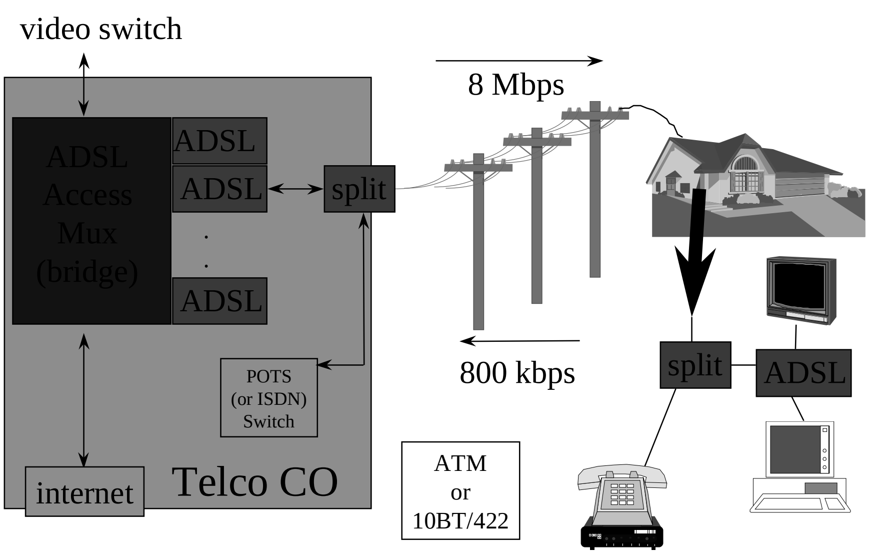
"Superhighway"



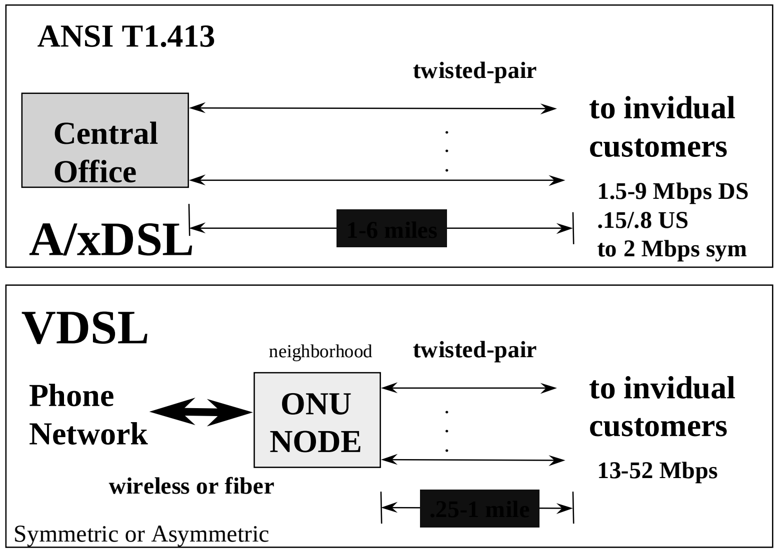
Twisted Pairs “xDSL”

- Avoid cost of new media deployment (fiber, HFC, coax, or wireless)
- over 100x increase in bit rates w.r.t. voiceband modems
- Incremental - pay for equipment on only those customers who ask for service
- Deploy sooner
- Problem: **HARD TRANSMISSION PROBLEM**

Asymmetric DSL (ADSL)



A/xDSL & VDSL



Other “x=“ ‘s

- Hdsl (symmetric 1.5, 2 Mbps)
- Sdsl (symmetric 384 kbps)
- Idsl (symmetric 160 kbps)
- software substitutions with respect to existing standards - “DSLAM”
- all rates within existing T1.413 or minor modifications

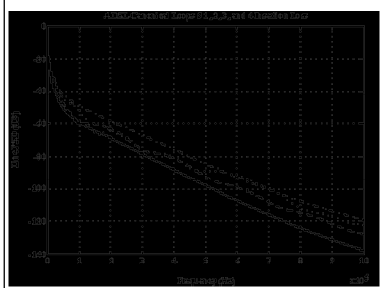
Outline

- Transmission Challenges
- DMT vs the transmission challenges
- ADSL and T1.413 Standard DMT
- V/XDSL and SDMT
- Implementation Truth

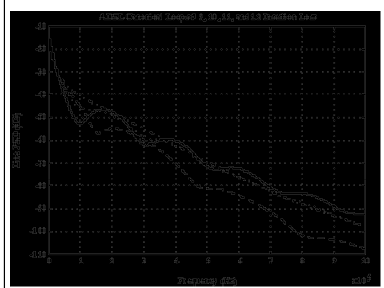
Twisted-Pair channels

- highly variable characteristics
- attenuation varies with
  - length
  - frequency
  - bridge taps
  - gauge

ADSL Loops

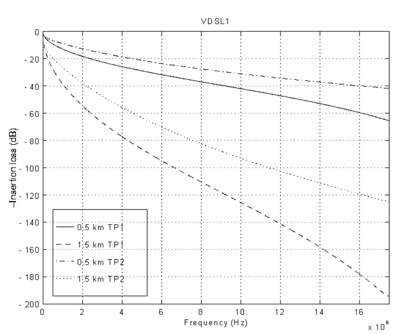


3-5 mile loops

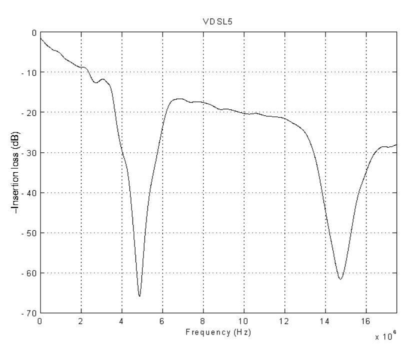


loops with bridge taps

VDSL Loops

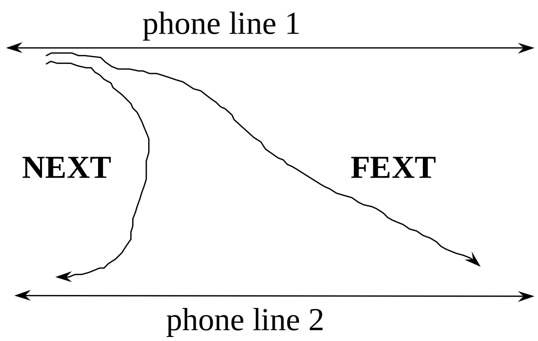


LOOP VDSL1



LOOP VDSL5

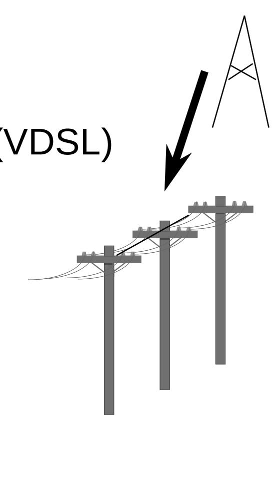
Crosstalk



Dominant noises, increased coupling at higher frequencies - must be mitigated in design
NEXT - $10^{-13} f^{1.5}$; FEXT - $10^{-19} d\,|H(f)|^2 f^2$

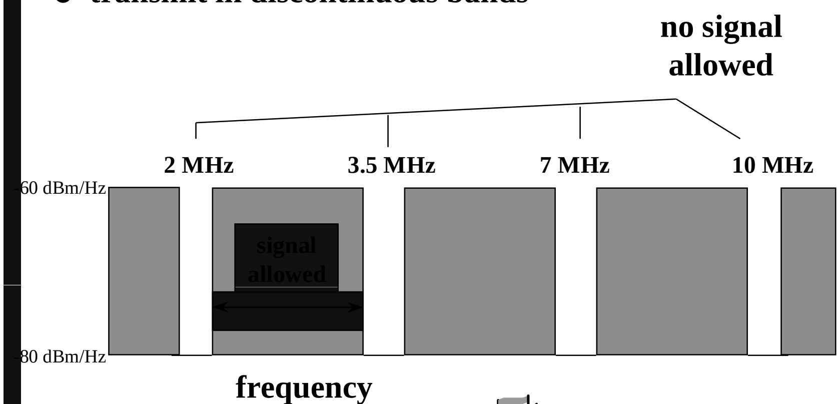
Other Noises

- Radio Noise, AM, HAM
  - 1 mW differential into rcvr
  - must reject HAM by 70-90 dB (VDSL) and AM by 20-40 dB (ADSL)
- Impulse Noise
  - 10's millivolts
  - 100's microseconds
  - narrowband (high amplitude)
  - broadband (low amplitude)



Radio Emissions

- like crosstalk, except into radio receivers
- **VDSL amateur (HAM) bands Public Safety bands**
- **transmit in discontinuous bands**



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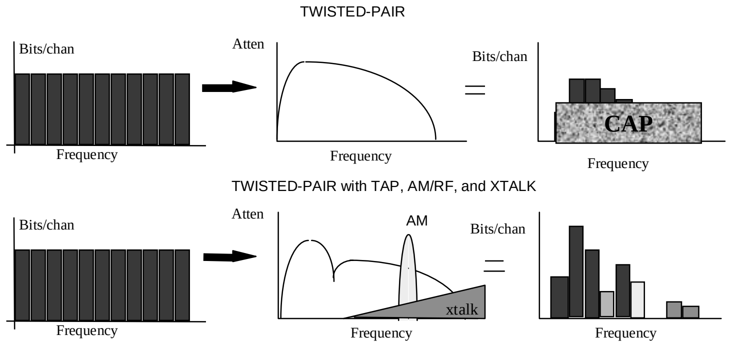
DMT Loading Basics

(adapts to each line)



600 Million phone lines and growing fast!

Bellcore tests, 1993 (ANSI Standard)

GTE tests, 1996 ; NSTL, 1996

Competitive Tests , CAP vs DMT

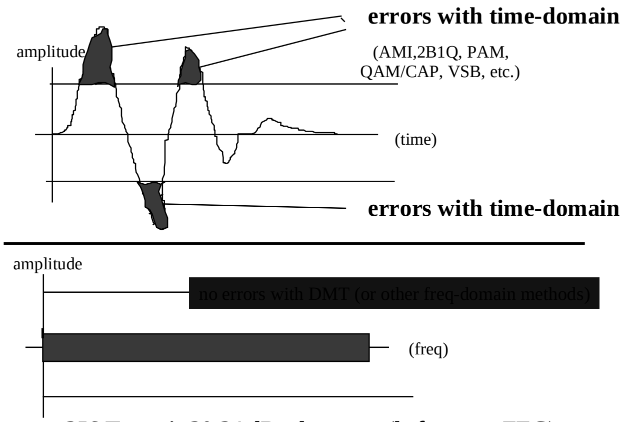
- **1993 - ANSI Bake off - 1.5 Mbps (Bellcore)**

	Loop 4	Loop 6	Loop 9	Loop 18
Amati DMT	+8	+7	>+16	> +10
RTEC QAM	-6	-8	+7	+1
ATT/WT CAP	FAIL	FAIL	FAIL	FAIL

- **Again 1996/7 - GTE**
- **1997 Tests - 6 Mbps/640 kbps**
  - CAP RADSL range limit - 1.5 km - coverage 50%
  - DMT range limit - >2.5 km - coverage 95%
  - 28 dB improvement
  - **DMT consumed less power !!**

DMT Impulse Control

- Low latency
- Less memory



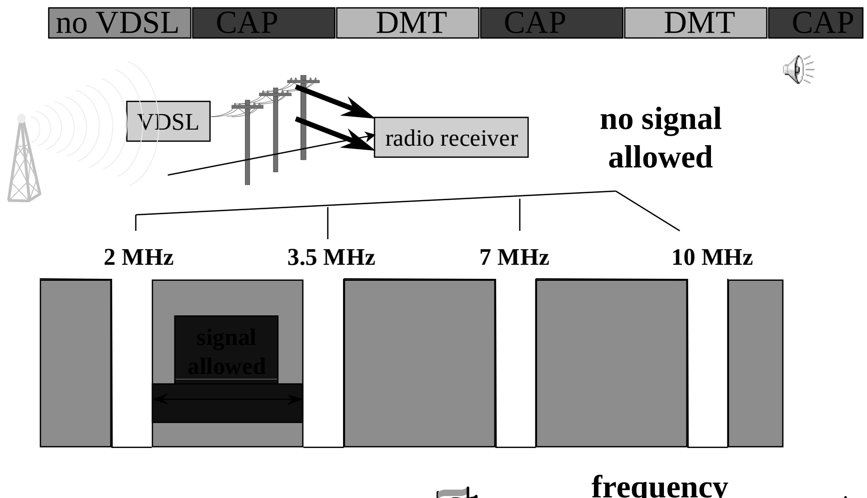
<u>**256 Tones is 20-24 dB advantage (before any FEC)**</u>

1996 Telchoice/NSTLResults

- See October 12 issue
- File transfer speeds with TCP/IP
- Amati DMT modem
  - 1.5M/160k ; 4M/384k (also 8M)
  - >99% of bit rate on file transfer
  - ranges from 15000 ft to 22000 ft
  - file transfer speed is several times CAP capability
- CAP modem used 7 Watts (DMT was 6.1W)

Radio Emissions

- like crosstalk, except into radio receivers (BT recording)



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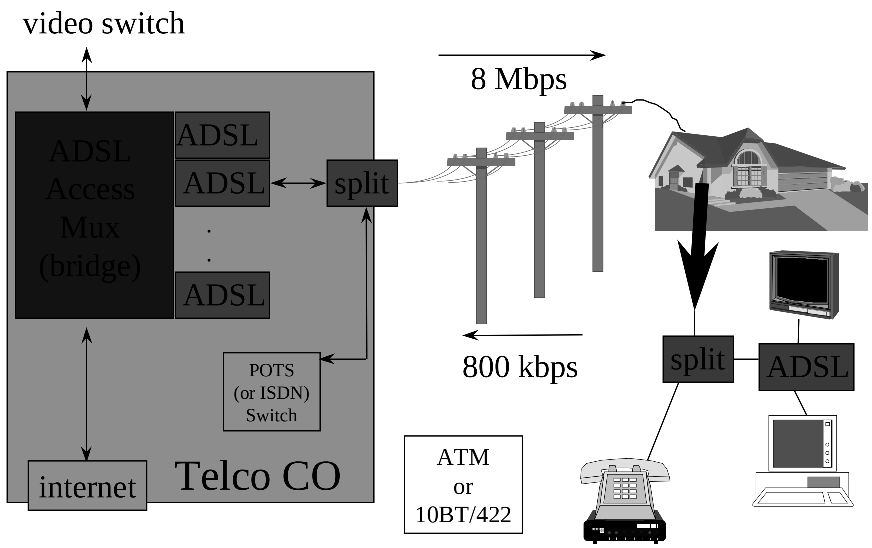
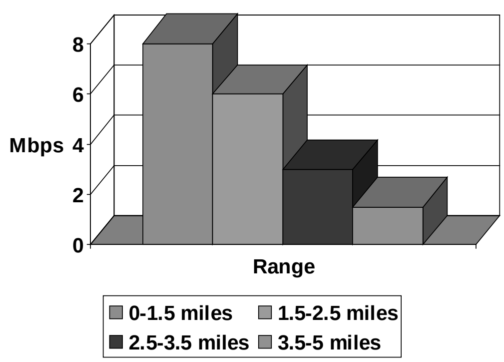
Asymmetric DSL (ADSL)



Rate Adaption



- DMT will rate adapt
- allows connection on almost any line at highest reliable rate
- match to internet use

Design Details - ADSL T1.413 (ANSI/ETSI)

- 256 tones - DMT, about 4 kHz (4.375)
- multiples of 32 kbps, Rate Adaptive
- Full training, OAMP primitives
- RS FEC, Trellis (4D Wei)
- fast/slow dual latency path
- Issue 2 now virtually complete, adds ATM
- ITU g.adsl standard evolving

DMT Suppliers/Customers - ADSL

- Suppliers - Alcatel, Amati, Analog Dev, Ericsson, Fujitsu, Motorola, NEC, Nokia, Nortel, Siemens, Texas Instruments
- Telco's - DT, FT, BT, Bezec, Swiss PTT, KT,Telstra, GTE, Pacific Bell, Ameritech, SW Bell, Bell South, HKT, Telia, ...

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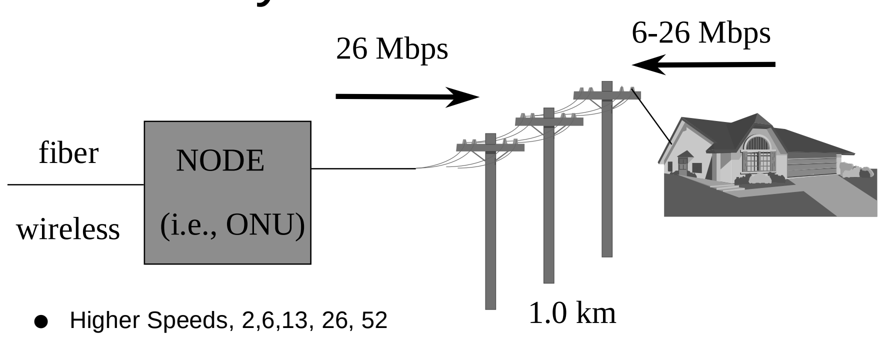
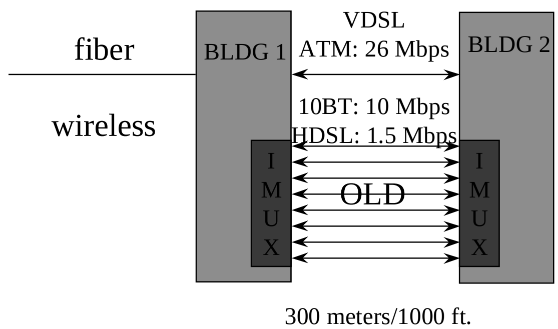
Asymmetric VDSL



- Higher Speeds, 2,6,13, 26, 52 Mbps
- Shorter Distances .5 to 3 km
- Symmetric and/or Asymmetric
- STANDARDS PROJECT
  - ANSI T1E1.4
  - ETSI TM6

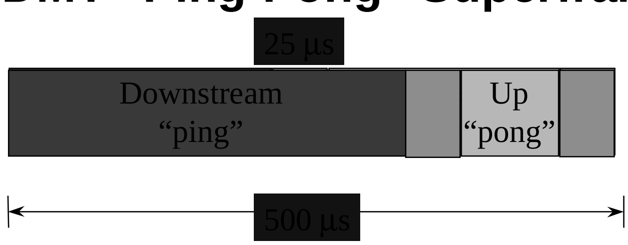
Similar to ADSL, except very low power requirement shorter distances and higher speeds.

Symmetric VDSL



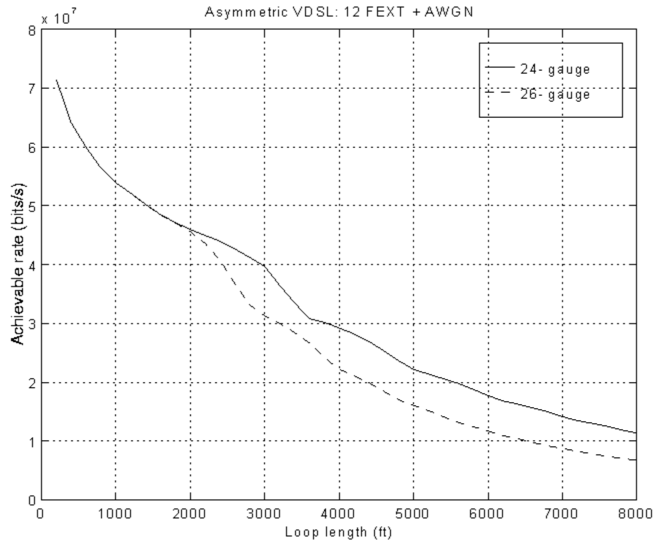
- Avoid Inverse Mux costs (large)
- connect buildings within campus
- Symmetric - early market is data com/enterprize net
- progress to full service as telco's evolve

SDMT "Ping-Pong" Superframe

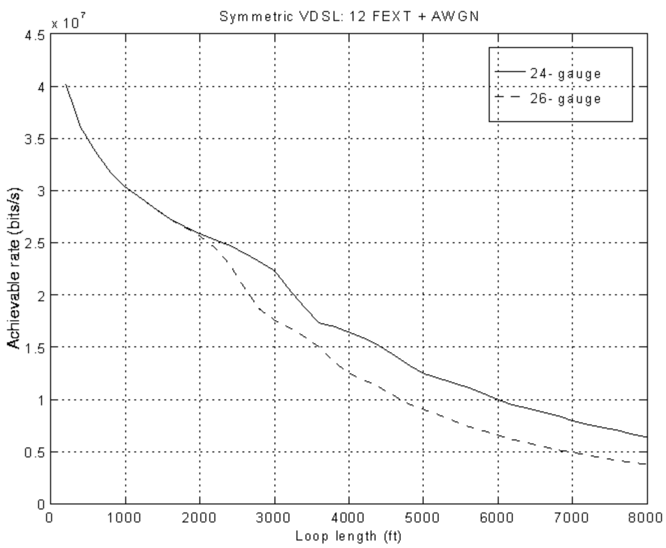


- Program length of "ping" and "pong" for asymmetric vs symmetric
- 500 microsecond frame/delay, synchronized
- SDMT Group to ANSI/ETSI:
  - Alcatel, Amati, Cadence, NEC, Rockwell, Samsung, Siemens, SGS-T, TI
- Amati/NEC version is 1997 - it's tiny! "Piccolo"

Asymmetric Range/Rate



Symmetric Range/Rate



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•Two VLSI approaches to “x”DSL

- Telecom semiconductor approach
  - (Motorola, Alcatel, SGS-T, ADI, NEC)
  - single chip integrated analog/digital
  - ATM interfaces - full service
- Datacom semiconductor approach
  - (Rockwell, TI, Amati, Mo-IS)
  - Heavy software
  - CO concentrates, modem changes through software

Power/Price of Concentrated solution

- < ADSL
- power under 1 W/line at CO
- Price - the power supply dominates at CO side
- RT is usual modem price

Conclusion

- TP transmission hard
- DMT excellent match
  - good performance
  - lowest power/cost
  - truly available
  - Widely deployed and in many Telco's network plans