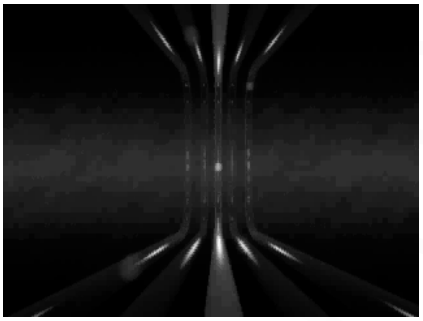
Copper Access



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Outline: Copper Access

1. DSL

   Twisted copper pairs includes advances with ADSL2+ (ITU-T G.992.5), SHDSL (ITU-T G.991.2) as well as the recent proposals of ADSL2++ and VDSL2.

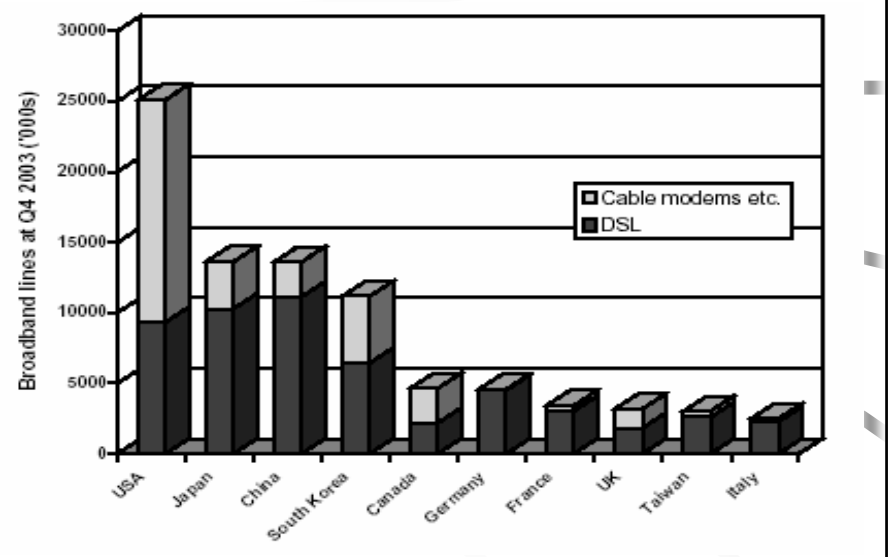
2. COAX

   Coax/CATV updates includes DOCSIS 2.0 (Data over Cable Service Interface Specification) and ITU-T (J.122).

3. PLC

   Powerline Carrier (PLC) includes Powerline telecommunication (PLT) and Broadband over Power Line (BPL) with updates from the ITU Radio Communication Sector (ITU-R) Sub Working Group (SWG) 6E1.

Cable/DSL Share in Top Ten Countries



Source: Point-Topic

COPPER-3

DSL Deployment (% per 100 phone lines)

South Korea	30.4
Taiwan	18.1
Iceland	18.0
Hong Kong	17.2
Belgium	13.8
Japan	13.0
Israel	11.6
Singapore	11.4
Denmark	11.1
Canada	10.2

Source: Point-Topic

COPPER-4

1. DSL

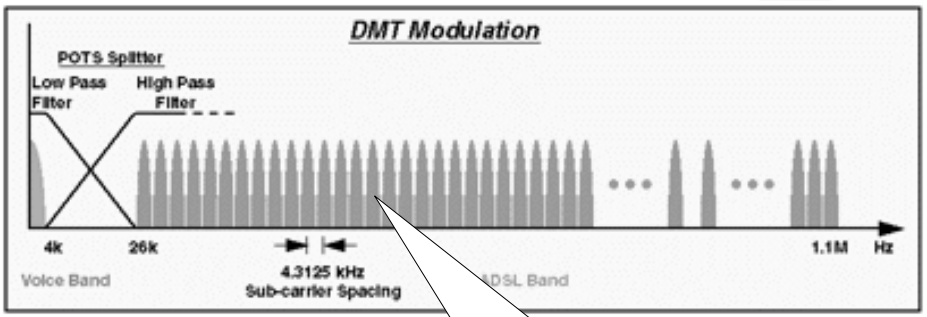
ITU-T Updates
G.992.5 = ADSL2plus

- Asymmetric Digital Subscriber Line
- ANSI T1.413-1998
- G.992.1 = G.dmt = 8.1/0.8 Mbps (down/up) using 256 bins
- G.992.2 = G.lite = 1.5/0.5 Mbps using 128 bins
- G.992.1 with S=1/2 line coding yielding 12 Mbps
- G.992.3 = G.dmt.bis (July2002) aka ADSL2
- G.992.3 Annex L = Reach Extended RE-ADSL2 (Oct2003)
- G.992.4 = G.lite.bis (May2002)
- G.992.5 = ADSL2plus = 24 Mbps at 5,000 feet (Jan2003)
- ADSL4 = 52 Mbps proposed quad spectrum (ADSL2++)

COPPER-5

DMT ADSL

- 4kHz low pass filter (LPF) for voice
- sub-carrier spacing for discrete multitones (DMT)



Pilot Tone #64 = 276kHz

COPPER-6

Three Down Stream (DS) Speeds

1. Theory
- Possible 256 bins, 12 Mbps max

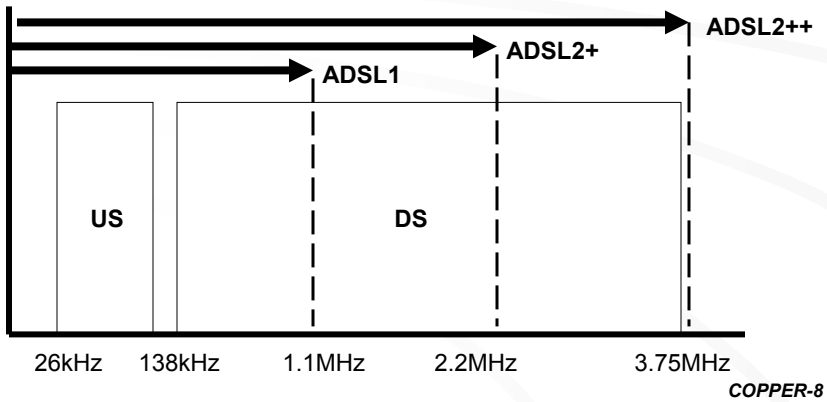
2. Actual
- Actual for the copper local access loop
- Perhaps 188 bins, 9.6 Mbps max
- Some bins disabled by the copper loop
- Will depend upon “bits per bin” loading

3. Tariff
- The service you requested, purchased
- Perhaps 140 bins, 1.5 Mbps max
- Some bins disabled by the service provider

COPPER-7

Quad Spectrum

- Extend the DS (Downstream) bins to 3.75 MHz
- Widen the US (Upstream) from 138kHz to 276 kHz
- Enhance the bit loading beyond 15 bits per bin



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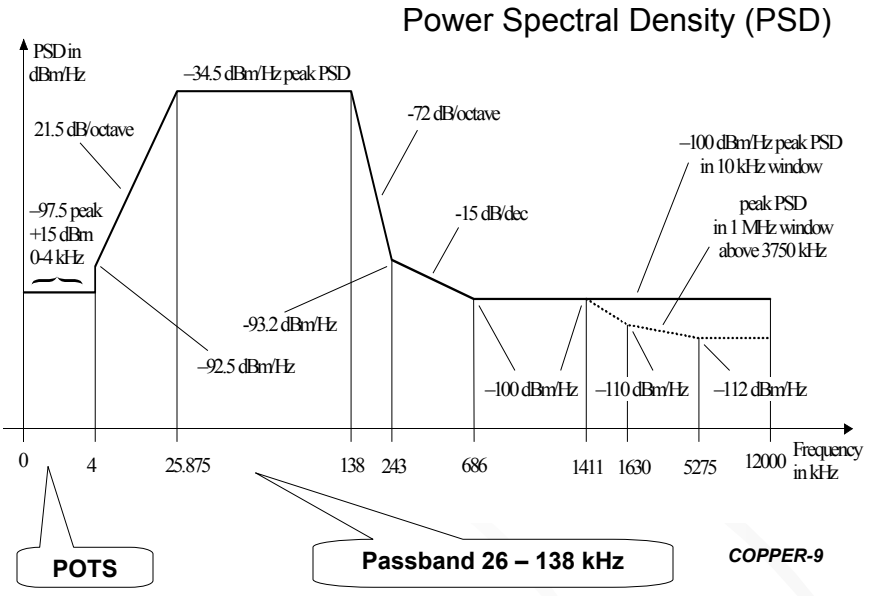
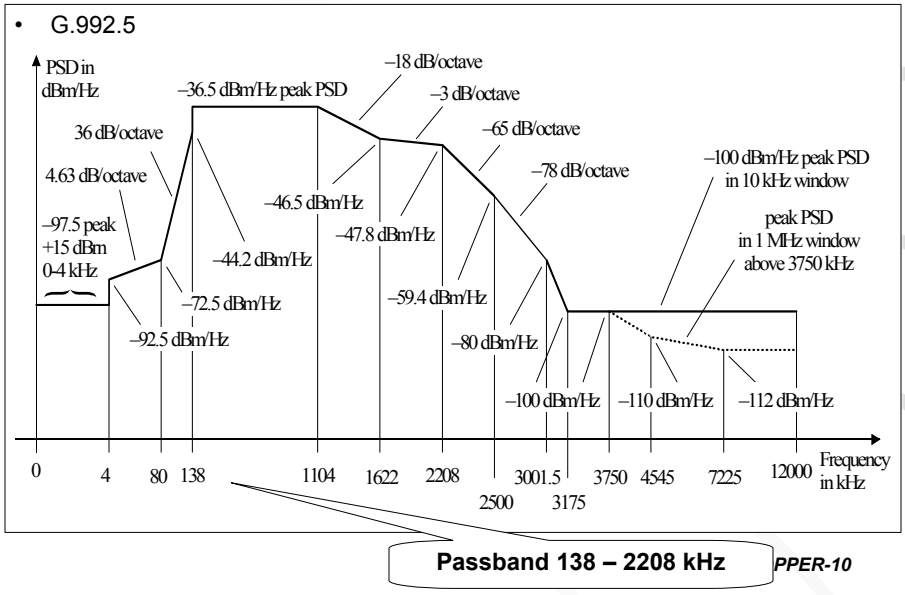
G.992.5 Upstream PSD (ADSL2plus)



G.992.5 Downstream PSD (ADSL2plus)



ANSI and ITU (G.dmt)

- ANSI T1.413 - 1998
- ITU-T G.992.1-1999 = ADSL (ADSL1)
- ITU-T G.992.3-2002 = ADSL2 (July 2002)
- ITU-T ADSL includes localization for different countries;
  - Annex A with POTS
  - Annex B with ISDN
  - Annex C with TCM-ISDN for Japan
  - Annex H for Japan
- G.992.1 has an enhanced activation compared to ANSI called G.994.1 (G.hs – handshake). Instead of a single tone being used to indicate optional features supported by a DSL modem, several tones digitally transmit the same information for a more robust startup.
- G.997.1 (G.ploam) -- management

G.992.3 (G.dmt.bis) = ADSL2

- ITU-T Study Group 15, Question 4 (SG15-Q4)
- May 2002 consent, July 2002 approved
- Technical freeze on ADSL
- ".bis" means "other" or second version
- Major changes in ADSL2 …
  - Improved bit rate in the downstream
  - Mandatory Trellis Code
  - Line Diagnostics
  - Reduced Power
  - All Digital Mode

G.992.3 (ADSL2) - Bonding

- ADSL2 provides support for inverse multiplexing
- Bonding of multiple copper pairs for transport of a
- Single ATM stream (ATM Forum Standard af.phy-0086.001 Inverse Multiplexing for ATM (IMA), Version 1.1)
  - 32 Mbps on 4 bonded pairs
  - 24 Mbps on 3 bonded pairs
  - 16 Mbps on 2 bonded pairs

G.992.3 (ADSL2) – Bonding Rates

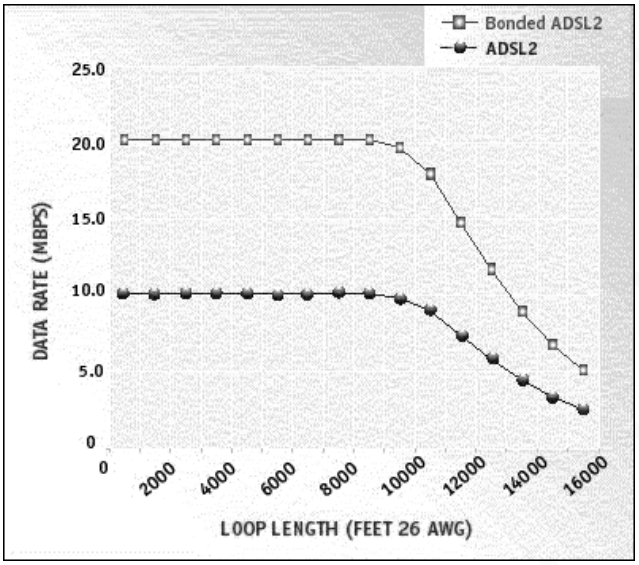
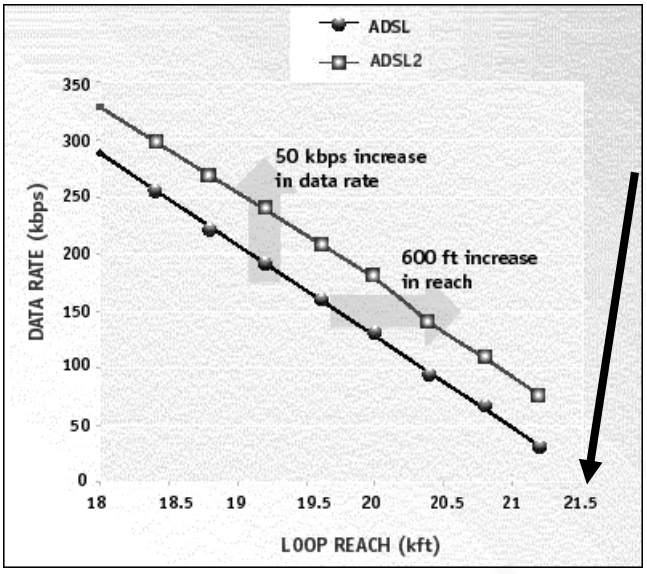


Diagram source: www.aware.com

G.992.3 (ADSL2) – Speed Change

- Improved bit rate
  - Was 2-15 bits, now also 1-bit signal constellations
  - four-dimensional, 16-state trellis-coded and 1-bit quadrature amplitude modulation (QAM) constellations
  - Results in a 96-192 kbps greater downstream
- Reduced framing overhead for faster transfers
- *Adaptable pilot tone* location (carrier #64 = 276kHz)
  - Will result in better clocking
- Mandatory Trellis coding and Reed Solomon RS=15
- Explicit rate negotiation
  - Will be good for multi-vendor configurations
  - Better tone reordering for RFI robustness

G.992.3 (ADSL2) – Rate & Reach



21.5 kft = 6.5 km

Diagram source: www.aware.com

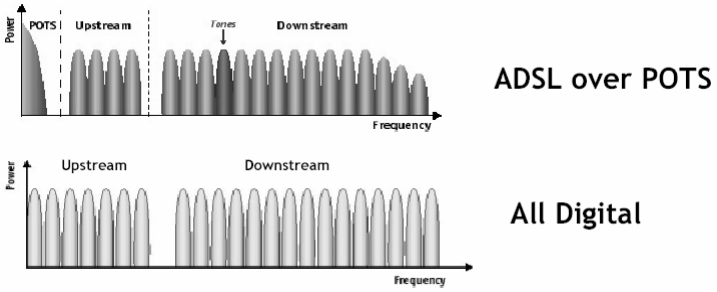
G.992.3 (ADSL2) – SRA

- ADSL2 can dynamically adapt to changes in line conditions:
  - Crosstalk from other DSL in the same cable
  - Narrow band AM (radio) disturbers
  - Temperature changes
  - Water in the cable bundle
- Uses online reconfiguration (OLR) when SNR changes
- SRA is important for video to avoid tiling (pixelization)
- Seamless rate adaptation (SRA) enables the transceiver to monitor line conditions and dynamically adapt the data rate “seamlessly”, i.e. without bit errors or requiring a service interruption for retraining

COPPER-17

G.992.3 (ADSL2) - Digital Mode

- All digital mode (no POTS, could have derived voice)
- About 256 kbps additional up stream data rate
- 0-26 kHz used for digital transmission not voice
- This option is not suitable for line sharing



PPER-18

ADSL2 DELT

- DELT (Dual-Ended Line Test)
- Defined by the ADSL2 (G.992.3)
- Enables the measurement of line conditions at both ends without dispatching maintenance technicians to attach test equipment to the end of the line.
- The information helps to isolate the location and the sources of impairments caused by crosstalk, radio-frequency interference and bridge taps.
- Data Collection is "DELT physical-layer technology"
- Data Processing is "Loop Identification"
- SELT (Single-Ended Line Test) future option

SELT/DELT Comparison

Feature/requirement	DELT support	SELT support
Loop topology		
Loop segment(s) length	Yes(longer loops)	Yes (shorter loops)
Loop segment gauge	Yes (longer loops)	Yes (shorter loops)
Bridge tap(s) location	Yes (longer loops)	Yes (shorter loops)
Bridge tap(s) length	Yes (longer loops)	Yes (shorter loops)
Bridge tap(s) gauge	Yes (longer loops)	Yes (shorter loops)
Loop Condition		
Load coil(s) existence	Not applicable	Yes
Load coil(s) location	Not applicable	Yes
Short on the line	Not applicable	Yes
Broadband loop noise characteristics	Yes	One direction
Broadband loop interference analysis	Option	Option
Requires line testing-enabled CPE	Yes	No
Requires dedicated or switched DSLAM port	No	Yes
Physical layer technology standardized	Yes	No
Loop identification technology standardized	No	No

Note: SELT=single-ended line testing **DELT**= dual-ended line testing

Source: Centillium

Single-ended and dual-ended line testing each have unique strengths and weaknesses for characterizing copper loops in ADSL deployments

G.992.3 (ADSL2) – Low Power

- L0 is ADSL2 full power mode
- L2 is low power mode at the ATU-C (DSLAM) while idle will result in better power especially for remote DLC (Digital Loop Carrier) configurations
- L3 is low power mode at the ATU-R (user) and ATU-C enables the modem to sleep when information is not being transmitted (e.g. overnight) – it takes 3 seconds to come out of L3 (sleep mode)

- Ability to disable tones to aid spectral compatibility
- Extended training intervals
- Power back off during startup

G.992.3 (ADSL2) – Ethernet

- ADSL2 includes a packet mode transmission convergence layer (PTM-TC) that enables connection of ADSL2 modems to packet services (Ethernet)
- Extensive configuration capability for PTM-TC with configuration of …
  - latency
  - bit error rate
  - minimum/maximum data rate to meet packet protocol requirements

Reach-Extended ADSL

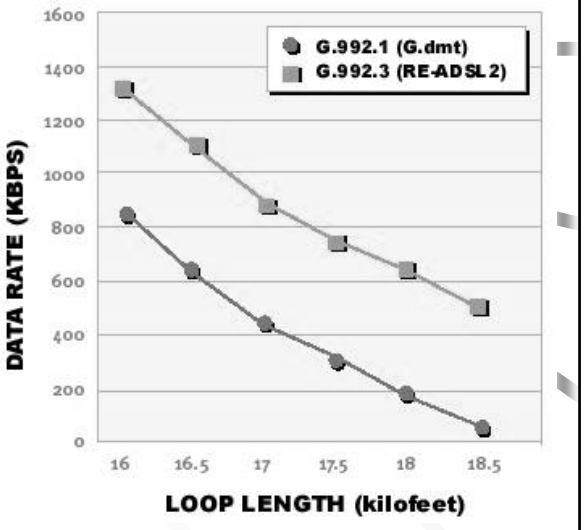
- G.992.3 Annex L
- Approved November 2003

- RE-ADSL2 performance improvements result from new power spectral density (PSD) masks designed to improve data rates on extra-long phone lines
- For downstream data rate of 384 kbps, results in 20%
- RE-ADSL2 is expected to operate as an alternative mode of an ADSL2 or ADSL2+ chipset that a carrier can choose to activate for particular customers

RE-ADSL2 (Down Stream Rate)

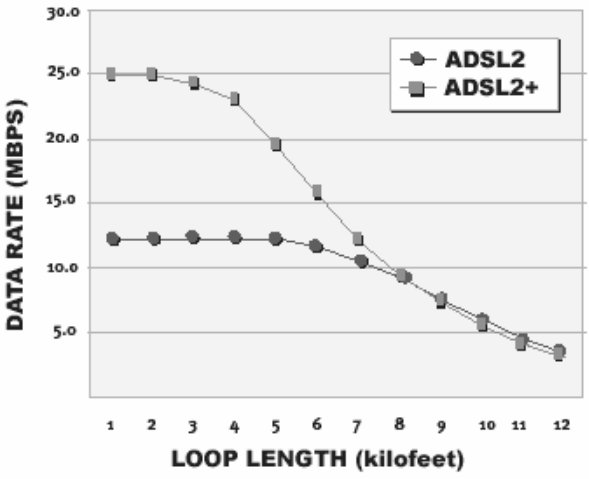
- 500 kbps at 18,500'
- 18,500' = 5.6 km
- 384 kbps at 28,000'
- 28,000' = 8.5 km

- RE is adding ½ km
- 1,500' = 0.460 km
- 26 AWG
- 12 other ADSL



G.992.5 (ADSL2+)

- 24 Mbps possible with 512 bins up to 2.2 MHz



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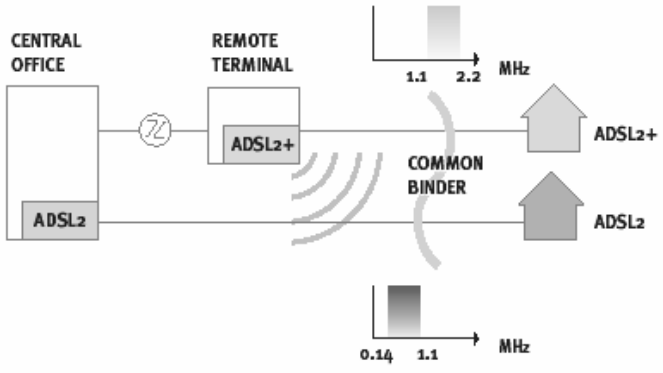
G.992.5 (ADSL2+)

- Possible to reduce cross talk by using different bins for different users
- Possible to mix ADSL2 (1.1 MHz) with ADSL2+ (2.2 MHz)



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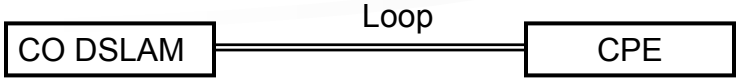
Annex Summary

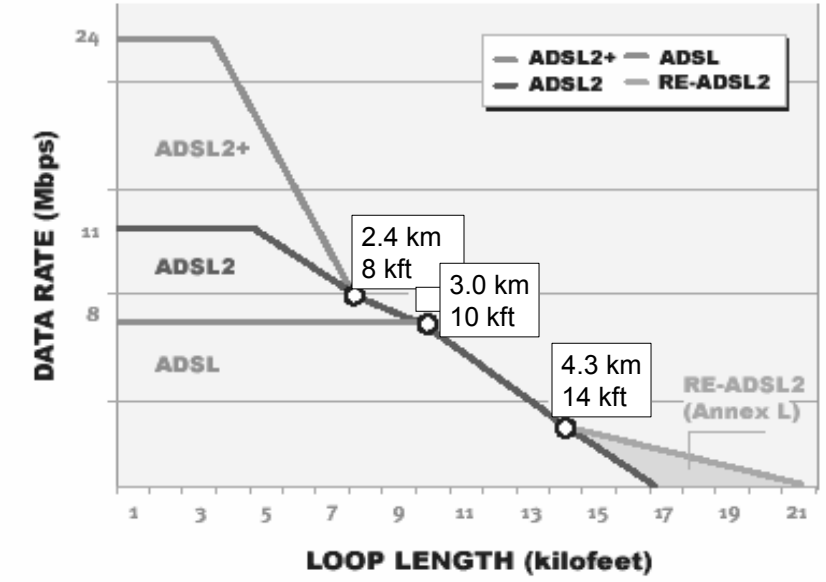
ANNEX	TYPE	#1 - 5 Bins =0 Hz	#6 - 31 =25.875 kHz	#32 - 64 =138.0 kHz	#65 - 255 =280.3 kHz	#256 - 512 =1.104 to 2.208 MHz
A (NA, EU, Asia)	POTS	POTS	UP	DOWN	DOWN	DOWN
B (Germany)	ISDN	ISDN	ISDN	UP	DOWN	DOWN
C (Japan)	TCM-ISDN	POTS	UP	DOWN	DOWN	N/A
I (Japan ADSL)	TCM-ISDN	POTS	UP	DOWN	DOWN	DOWN
I (Japan ADSL2)	POTS	UP	UP	DOWN	DOWN	N/A
I (Japan ADSL2+)	POTS	UP	UP	DOWN	DOWN	DOWN
J (All Digital)	ISDN	UP	UP	UP	DOWN	DOWN
L (RE-ADSL2)	POTS	POTS	UP	DOWN	DOWN	N/A
M (ADSL2+) More Upstream	POTS	POTS	UP	UP	DOWN	DOWN

Automode



1. ADSL2 would connect at 690 kbps for CPE at 18,000 feet (4.5 km). Instead …
2. ADSL2/ADSL2+ CO collects loop data during initialization and training
3. Automode determines RE-ADSL2 is the best configuration based on line conditions
4. DSLAM configures customers port for RE-ADSL2 mode
5. CPE line at 1.1 Mbps (a 160% improvement over ADSL1)

Summary of Rate/Reach



DSM (Dynamic Spectrum Mgmt)

- **DSM level 0**
  - No coordination
- **DSM level 1**
  - Distributed multi-user power allocation
  - Implementation of Iterative Water Filling (**IWF**)
- **DSM Level 2**
  - Centralized multi-user power allocation
  - Optimal Spectrum Management (**OSM**)
- **DSL Level 3**
  - Multi-user detection
  - Also called vectoring

SHDSL

- Single-Pair High-bit-rate DSL (SHDSL)
- 16 level TC-PAM line coding
- Trellis Coded Pulse Amplitude Modulation (TC-PAM)
- ITU G.991.2 approved April 2001 (was G.shdsl)
  - 2-wire (2.36/2.36) … 192 kbps steps
  - 4-wire (4.7/4.7) … 384 kbps steps
- STU-R connects to STU-C
- Very good spectral compatibility with other services
- Some vendors are providing SHDSL over POTS

VDSL2

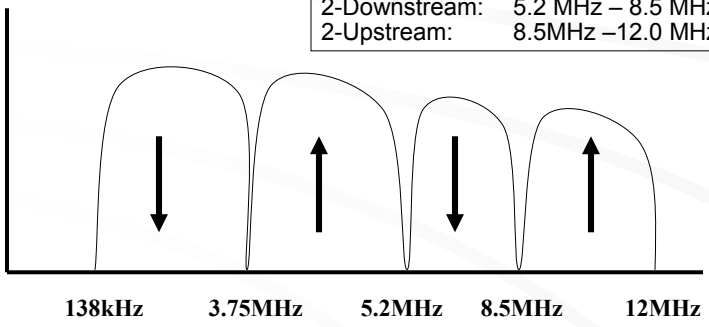
- Very-High-Data-Rate Digital Subscriber Line
- Standards track
- Downstream rates:
  - 12.96 Mbps (4,500 ft.– 1500m)
  - 25.82 Mbps (3,000 ft.– 1000m) = FTTN (Fiber-to-the-Node)
  - 51.84 Mbps (1,000 ft. – 300m) = FTTC (Fiber-to-the-Curb)
- Upstream rates from 1.6 to 2.3 Mbps
- Symmetric rate (13 Mbps) possible
- Simpler than ADSL
  - Shorter lines, fewer transmission constraints
  - Ten times faster
- Enables multiple video streams
- HDTV compatible (19 Mbps or 10 Mbps compressed)

VDSL2 Spectrum

- Frequency Plan 998

Frequency Plan 998

1-Downstream:	138 kHz –3.75 MHz.
1-Upstream:	3.75 MHz –5.2 MHz
2-Downstream:	5.2 MHz – 8.5 MHz
2-Upstream:	8.5MHz –12.0 MHz



Cable/DSL Split as of 31Dec2003

- Worldwide
  - 64.1 Million / DSL (+32.1% in 2H 2003)
  - 36.8 Million / CATV (+18.2% in 2H 2003)
- Canada
  - 2.2 M / DSL(+16.2%)
  - 2.5 M / CATV(9.9%)
- USA
  - 9.3 M / DSL(+24.8%)
  - 15.8 M / CATV(+18.0%)

DSL Forum Updates (Examples)

- DSL Forum issues Technical Reports (TRs)
- TR-046 "Auto-Configuration: Architecture & Framework"
- TR-059 “Support of QoS-Enabled IP Services”
- TR-066 “ADSL Network Element Mgmt”
- TR-067 “ADSL Interoperability Test Plan”

Reference: www.DSLFORUM.org

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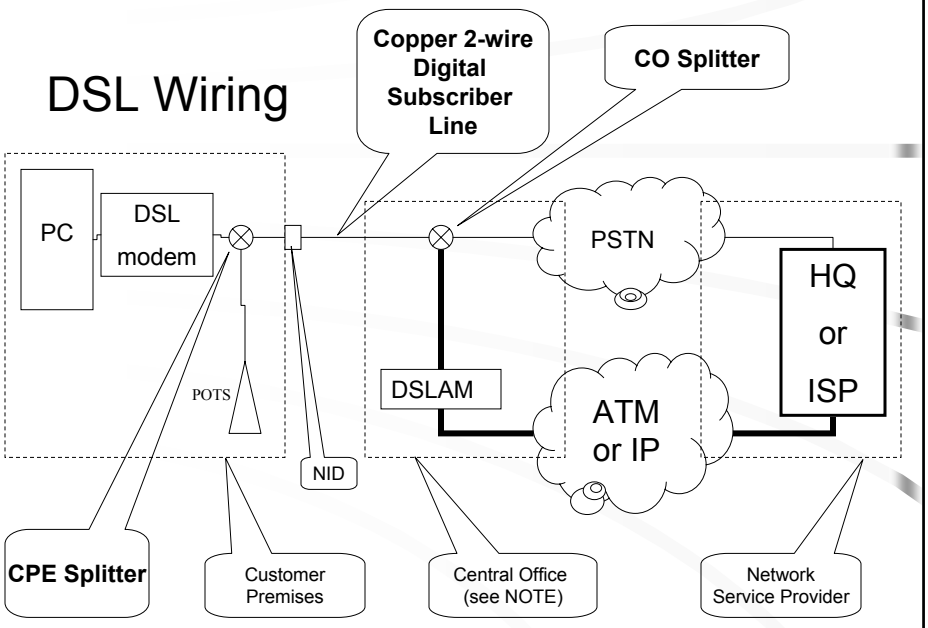
DSL Wiring



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CPE Modem/Router Examples

- Siemens SpeedStream 5600 SOHO Router ADSL2+
- Comtrend CT-536Plus 802.11g Wireless ADSL2+
- Thomson Speedtouch ST620 ADSL2+/ADSL2/RE

COPPER-37

CPE DSL Gateway

- Residential Gateway
- Provides …
  - Sharing of a high speed DSL line
  - LAN interface (Ethernet hub, USB, HomePNA)
  - Optional wireless support IEEE 802.11b, HomeRF, HomePlug
  - HomePNA (Home Phoneline Networking Alliance)
  - HomePlug (HomePlug Powerline Alliance)
  - Optional firewall protection
  - DHCP, NAT support

- Examples;
  - http://www.2wire.com
  - http://www.netopia.com/

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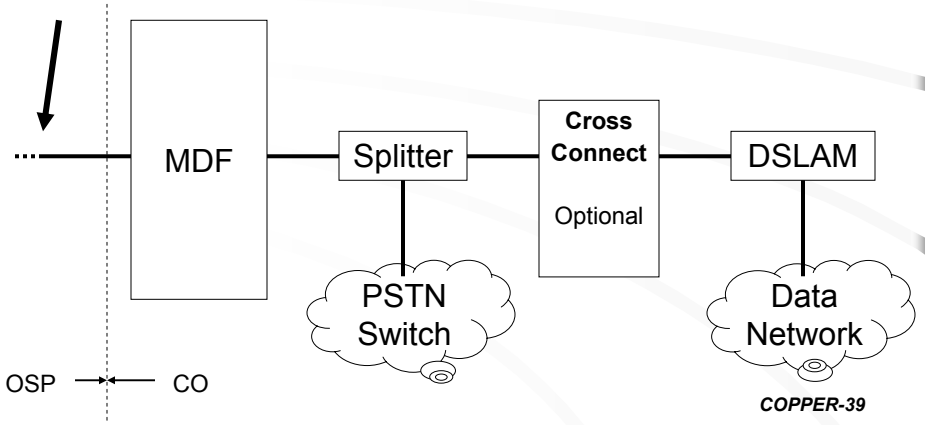
DSL Central Office Equipment

OSP (Outside Plant) termination inside the CO



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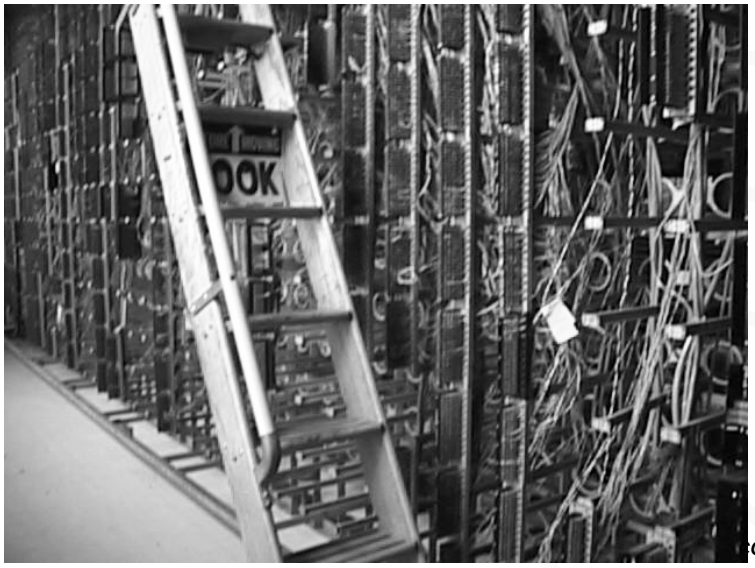
MDF (Main Distribution Frame)

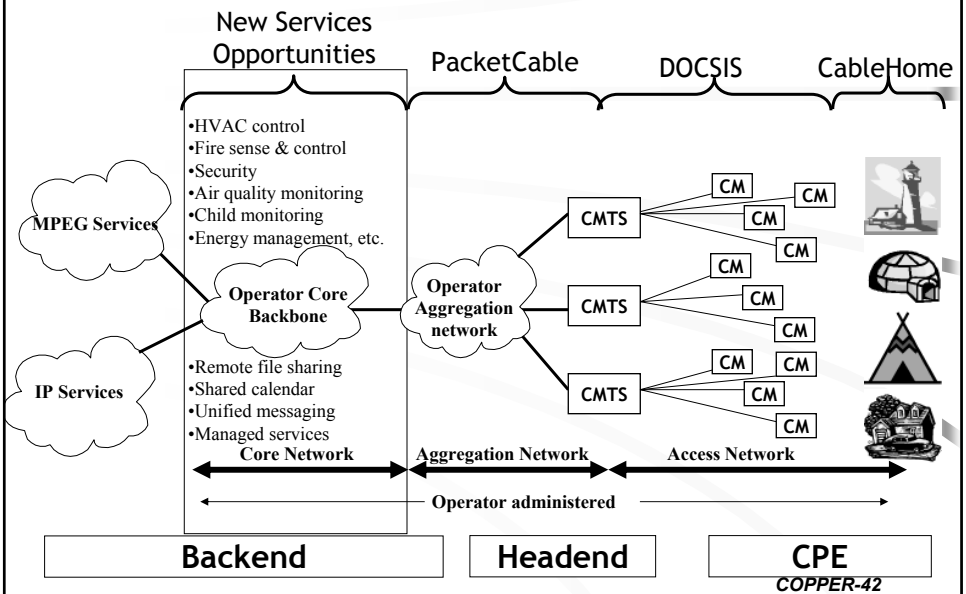


COPPER-40

2. Coax Cable

- Coax/CATV hybrid coax and fiber
- ITU-T J.122
- PacketCable
- DOCSIS
- CableHome

Cable Architecture



DOCSIS 2.0 Overview

- Symmetrical services are enabled by DOCSIS 2.0
  - 1.5x greater efficiency
    - operates at 64 QAM
  - 2x wider channels
    - new 6.4 MHz wide channel
- DOCSIS 2.0 widens the pipe for IP traffic, allowing cable providers to create more and better services for voice, video, and data
- It does this by using enhanced modulation and improved error correction
- Superior ingress and impulse noise performance

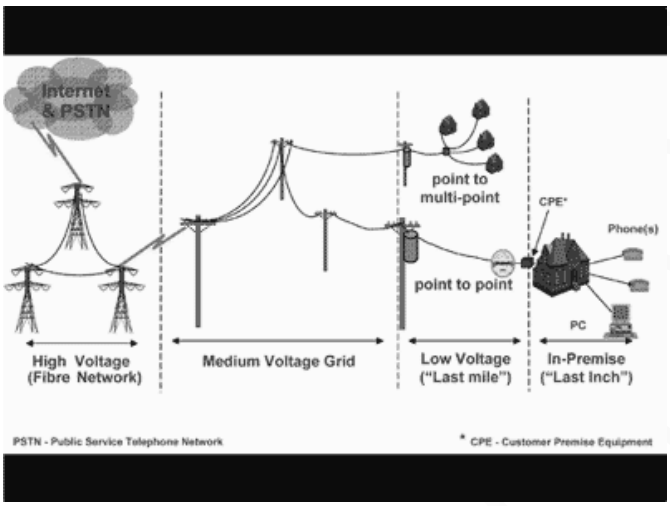
DOCSIS™ Road Map

DOCSIS	Key Features	Benefits/ Services
DOCSIS 2.0 (30 Mbps u/s)	• **Mandatory S-CDMA/ TDMA** • **Best of DOCSIS**	• **Symmetric services** • **Peer-to-peer** • **Business-to-business (20 T1 capacity)**
DOCSIS 1.1 (10 Mbps u/s)	• **QoS** • **Pre-EQ** • **Operations** • **Security**	• **Tiered service** • **Double u/s capacity** • **Lower op's costs** • **Better than competitor**
DOCSIS 1.0 (5 Mbps u/s)	• **Spec'd for retail** • **Standard spec**	• **High speed data** • **Internet access**

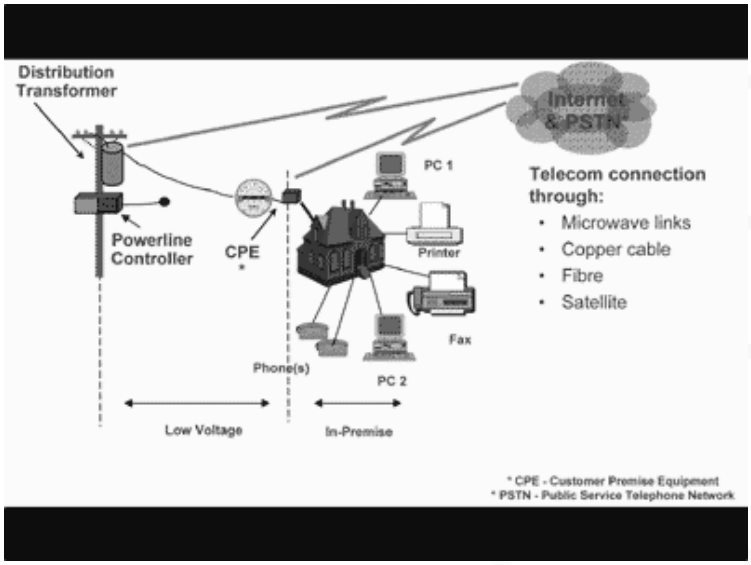
3. PLC (Power Line Carrier)

- Power Line Telecommunication (PLT)
- Broadband over Power Line (BPL)
- ITU Radiocommunication Sector (ITU-R) Sub Working Group (SWG) 6E1 concerned about interference with radio broadcasters
- Low data rate PLC systems utilize frequencies in the range 9 kHz and 525 kHz
- BPL uses carrier frequencies in the range 2 - 30 MHz

PLC (Power Line Carrier)



PLC



Copper Access Summary

1. DSL
   - Based on the 1 billion copper access loops
   - 64.1 Million installed by Jan 2004
   - ADSL2+ at 24 Mbps standardized by ITU-T G.992.5
   - ADSL2++ proposed at 52 Mbps

2. Coax/CATV
   - 36.8 Million installed by Jan 2004
   - ITU-T J.122

3. PLC
   - ITU-R in discussion