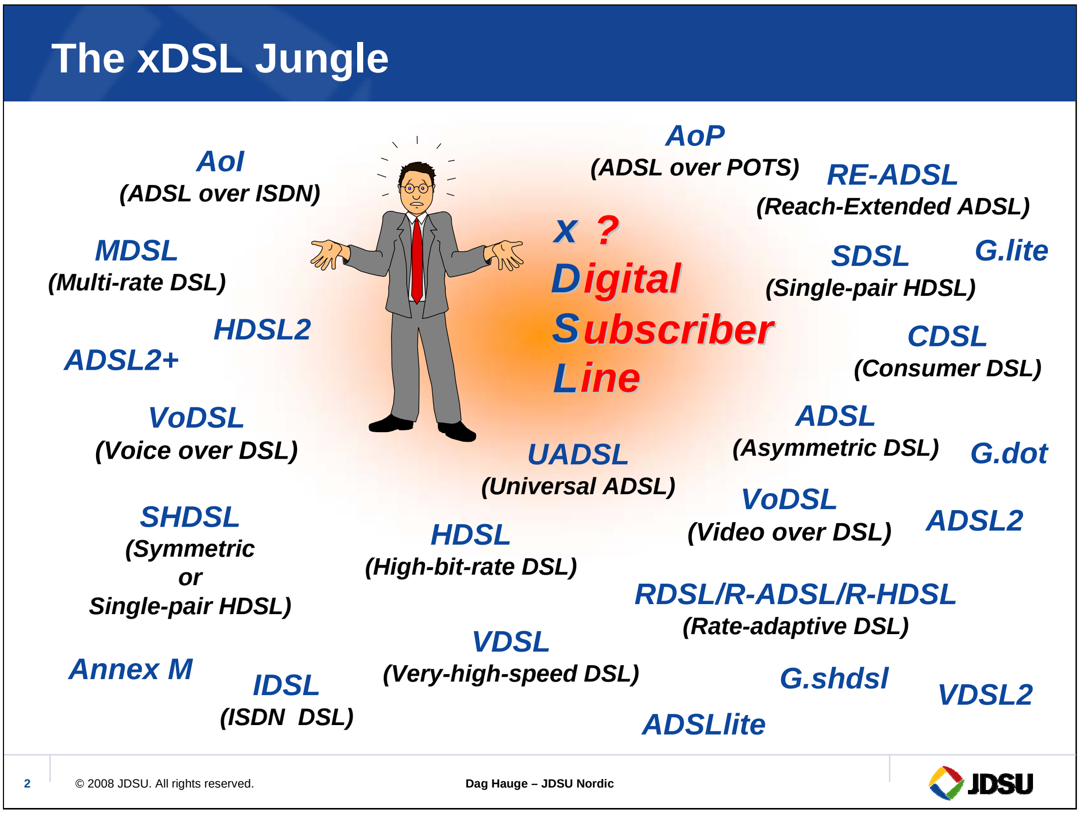
SmartClass ADSL/Copper Combo Kickstart Training

Lasse Kaae

Version 3.0



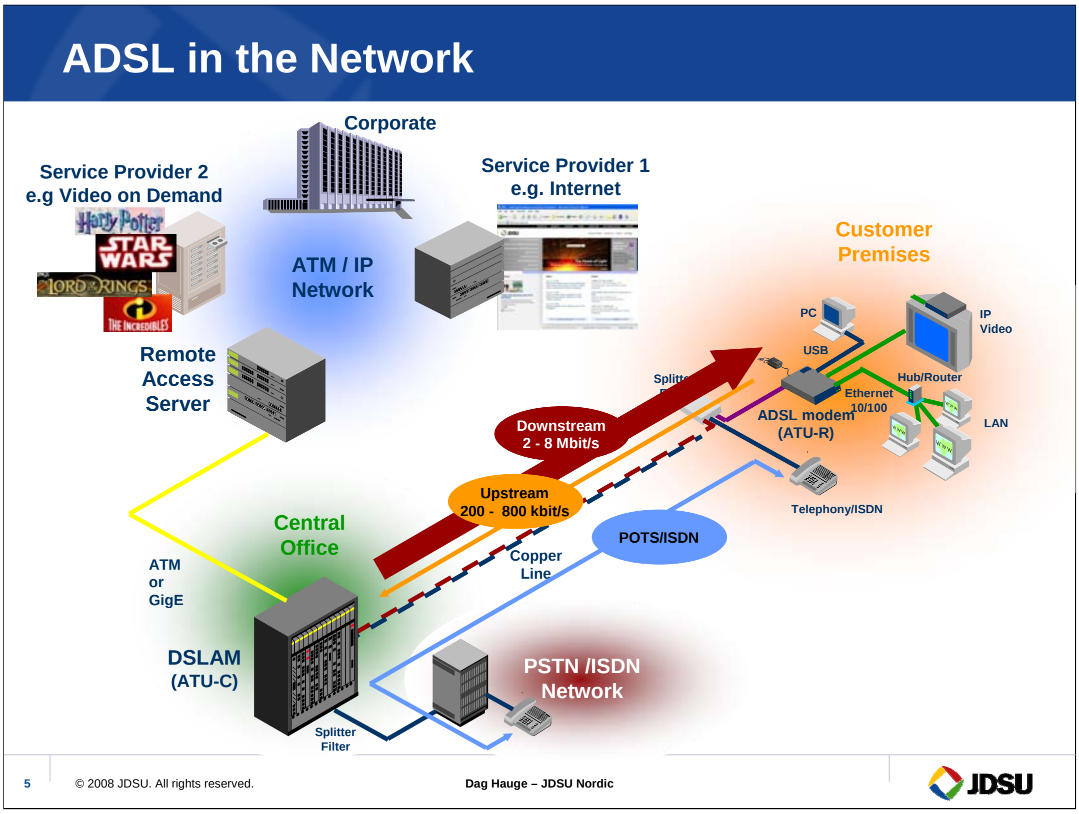
The ”x” in xDSL stands for the various kinds of digital subscriber line technologies, including HDSL, ADSL SDSL and VDSL. To fully grasp the significance of these technologies and the applications for which each is best suited, it is important to understand how they differ. Key points to keep in mind are the trade-offs between signal distance and speed, and the differences in symmetry of upstream and downstream traffic.

ADSL Key Facts

- ADSL means Asymmetric Digital Subscriber Line
- Main application today is high-speed broadband connection to residential users for Internet and Triple Play
- DMT (Discrete Multi Tone modulation) is a worldwide standard line code
- ITU-T G.992.1 (ex. G.dmt)
  - Annex A: ADSL over POTS (AoP)
  - Annex B: ADSL over ISDN (AoI)
- ITU-T: ADSL shall support data rates downstream at all integer multiples of 32 kbit/s from 32 kbit/s to 6 144 kbit/s and upstream at all integer multiples of 32 kbit/s from 32 kbit/s to 640 kbit/s
- Overlapped or non-overlapped frequency spectrum
- New standards ADSL2 and ADSL2+

An ADSL system shall support data rates at all integer multiples of 32 kbit/s up to 6 144 Mbit/s downstream and up to 640 kbit/s upstream.

The transport capacity of the ATU system is defined only as that of the bearer channel. When, however, an ADSL system is installed on a line that also carries POTS or ISDN signals, the overall capacity is that of POTS or ISDN plus ADSL



This slide illustrates in a more practical manner how ADSL operates in the telecommunication network.

ADSL uses a pair of copper and interconnects two modems to deliver broadband services. One modem is installed at the Central Office as a part of a so-called DSLAM (Digital Subscriber Line Access Module) which is more or less the cornerstone of the DSL solution.

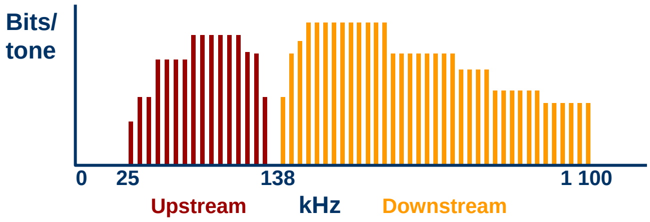
Functionally, the DSLAM concentrates the data traffic from multiple DSL loops onto the backbone network interface for connection to service providers offering Internet, video etc.. The DSLAM provides backhaul services for packet, cell and/or circuit-based applications through concentration of the DSL lines onto Ethernet, E1/E3 or ATM.

At the opposite end of the copper line, at the customer premises, we find the other modem (ANT, ADSL Network Termination) for the service user's connection to the DSL by means of typically interfaces like 10BaseT, V.35, ATM-25 or E1.

At the Central Office and customer premises we also find the POTS or ISDN splitter which is a device allowing the copper line to be used for simultaneous high-speed data transmission and telephone service.

By terminating the ADSL traffic in the Central Office, the traffic will not enter the PSTN/ISDN networks and as such these networks are off-loaded.

ADSL and DMT (Discrete Multi Tone)



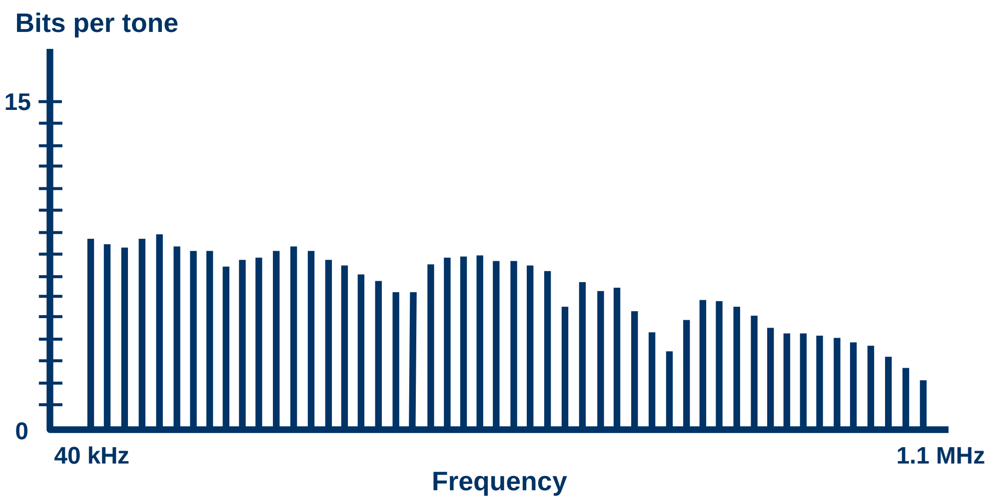
- Worldwide standard line code for ADSL
- Wideband variable spectrum signal
- Bit swapping helps to adapt to loop problems
- Maintains BER $<10^{-7}$
- Many ways of carrying IP over ATM

- 256 Carrier tones (512 for ADSL2+)
- Each tone carries a QAM signal
- 4.3125 kHz/tone
- 4096 baud/tone
- Up to 15 bits/Baud (bits/tone)
- 0 to 61.440 bits/second/tone

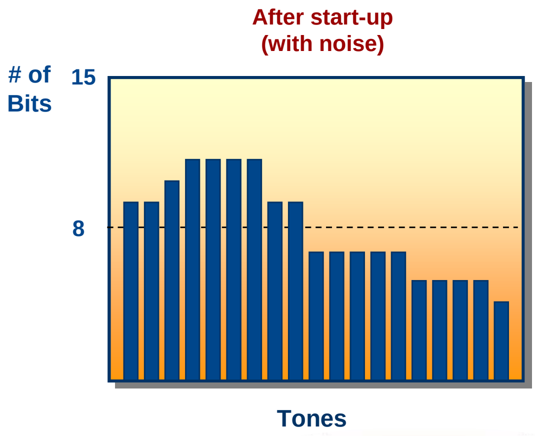
Although ADSL is characterized predominantly by its FEXT-exploiting frequency planning, allowing it to go fast and far, most of the debate has been around the line codes used for ADSL. The worldwide standard for ADSL is Discrete Multitone or DMT. DMT is a multicarrier format, modulated by means of an inverse-FFT.

DMT for ADSL uses a 255 point complex FFT to produce up to 255 carriers each using QAM modulation. The carriers are spaced 4.3125 kHz apart. The downstream typically uses spectrum up to 1.1 MHz, and the databits to be carried are assigned to the individual carriers according to the signal-to-noise profile of the line. As a result, DMT can flexibly avoid interference isolated in parts of the spectrum simply by re-allocating bits. This allows robust transmission without altering the transmit spectrum.

Signal to Noise Ratio (SNR) and DMT



DMT Bit Swapping

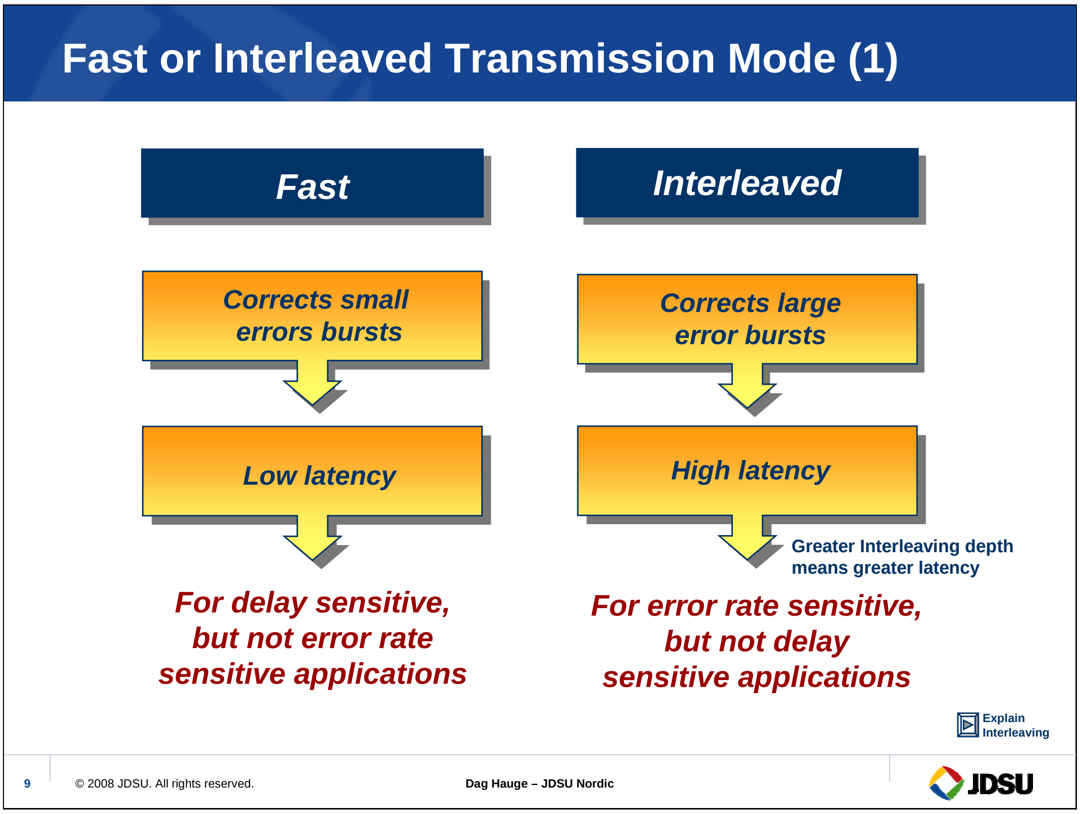


Need to React to:

- Crosstalk
- RFI
- Bridged taps
- Impulse Noise
- Wet sections
- Line Length
- Split Pairs

Adaptation:

- BER $<10^{-7}$ needed to maintain sync
- DMT is a Wideband signal
- Attenuation and Noise measured
- It shapes its spectrum to adapt



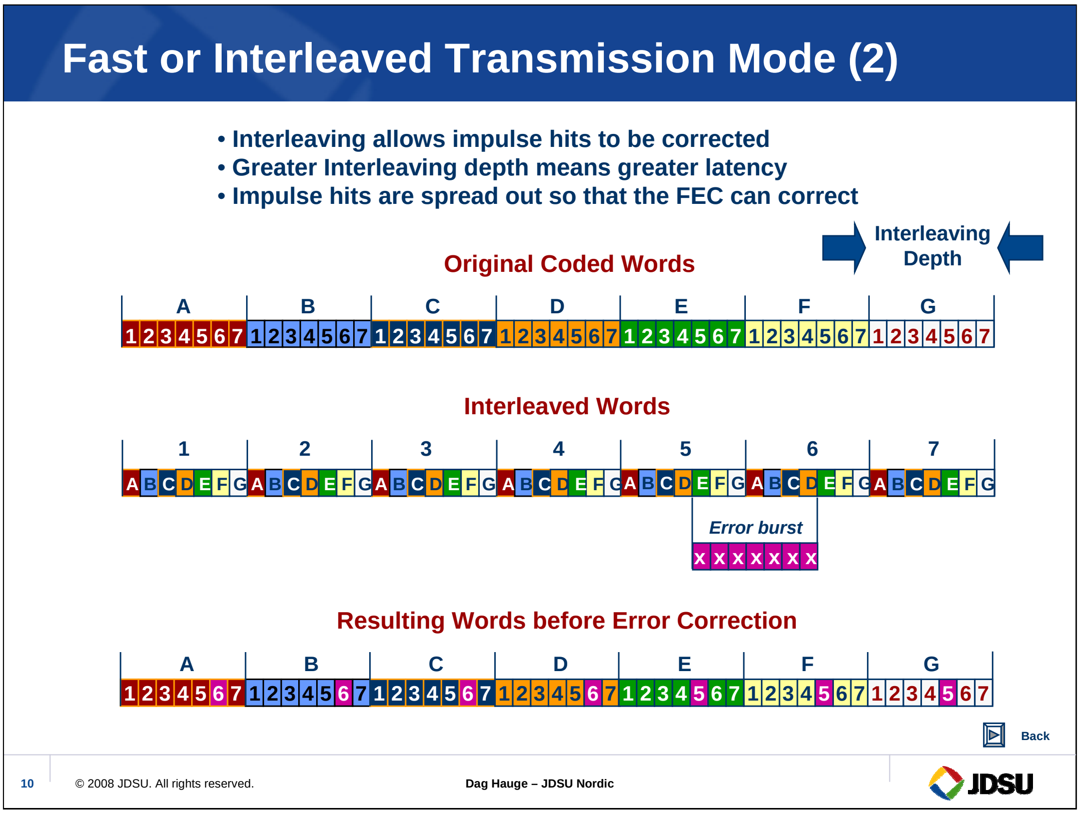
ADSL and VDSL standards have defined two data paths through each modem.

One is with deep interleaving and the ability to correct long error bursts. However, this will introduce latency in the transmission path, which is not acceptable for all applications.

The other path is without interleaving, or with only short interleaving, for applications that can tolerate error bursts, but not long delays.

For each application, a virtual circuit (VC) through the path best suited for this application will be established.

Services which are both delay-sensitive and error rate-sensitive (to some extent) are not know at the time being.



Interleaving the coded message before transmission and de-interleaving after reception causes bursts of channel errors to be spread out in time and thus to be handled by the decoder as if they were random errors. The interleaver shuffles the code symbols over a span of several block lengths (for block codes) or several constraints lengths (for convolutional codes). The span required is determined by the burst duration. The details of the bit re-distribution pattern must be known to the receiver in order for the symbol stream to be de-interleaved before being decoded.

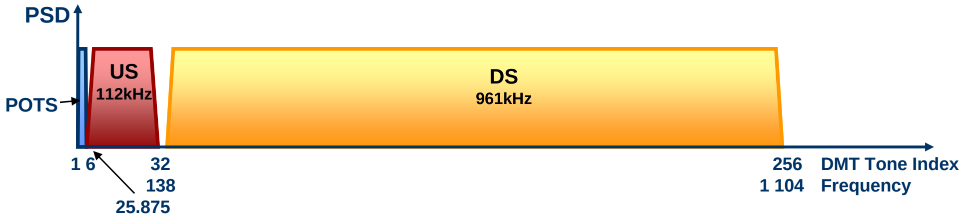
The uninterleaved code words are A through G. Each code word is comprised by seven code symbols. Let us assume that code has a single-error correction capability within each seven-symbol sequence. If the memory span of the channel is one code word in duration, such a seven symbol time noise burst could destroy the information contained in one or two code words. However, suppose that, after having encoded the data, the code words were then interleaved or shuffled. That is, each code symbol of each code words is separated from its pre-interleaved neighbours by a span of seven symbol times. Now, the seven symbol time noise burst affects only one code symbol of the original seven code words. Upon reception, the stream is first de-interleaved so it resembles the original coded sequence. Then the stream is decoded. Since each code word can correct a single error, the burst noise has no degrading effect on the final sequence.

Deep interleaving for correction of long error bursts introduces latency in the transmission path, which is not acceptable for all applications. ADSL and VDSL standards have therefore defined two data paths through each modem, one with deep interleaving and the ability to correct long error bursts, and the other without interleaving, or with only short interleaving, for applications that can tolerate error bursts, but not long delays. For each application, a virtual circuit (VC) through the path best suited for this application will be established.

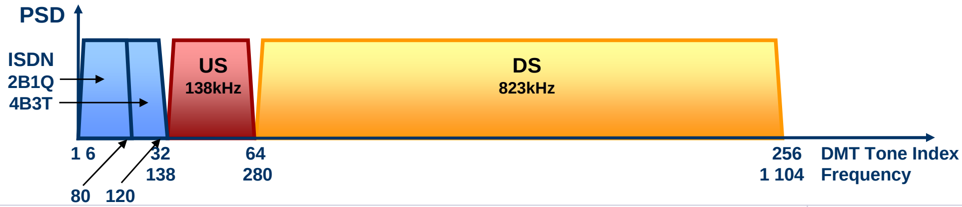
ADSL over POTS vs. ADSL over ISDN

ITU-T G.992.1 Annex A vs. Annex B

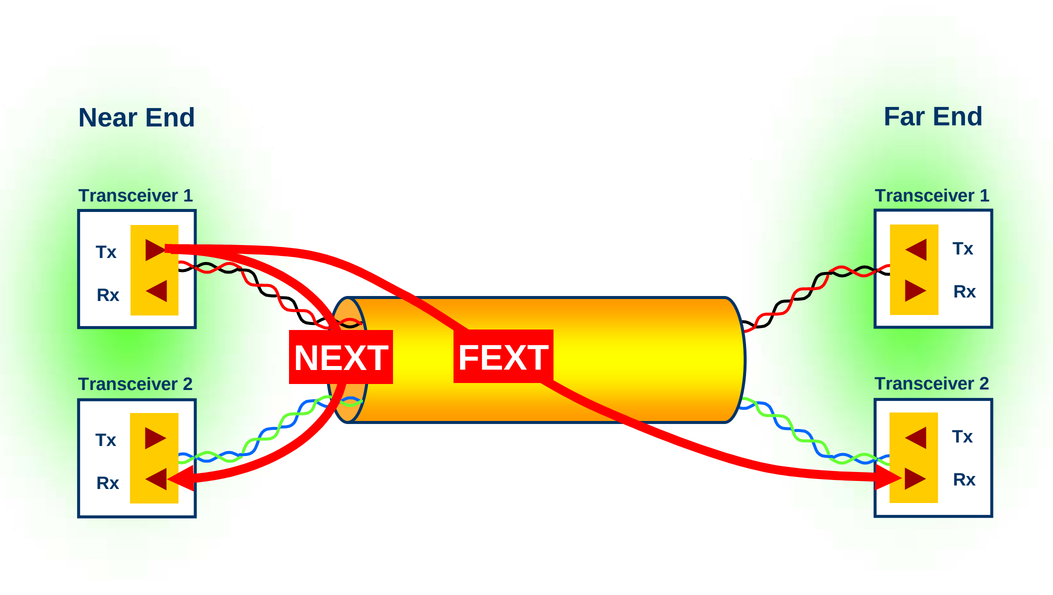
ITU-T G.992.1 Annex A, AoPOTS, Non-overlapped spectrum (FDM)



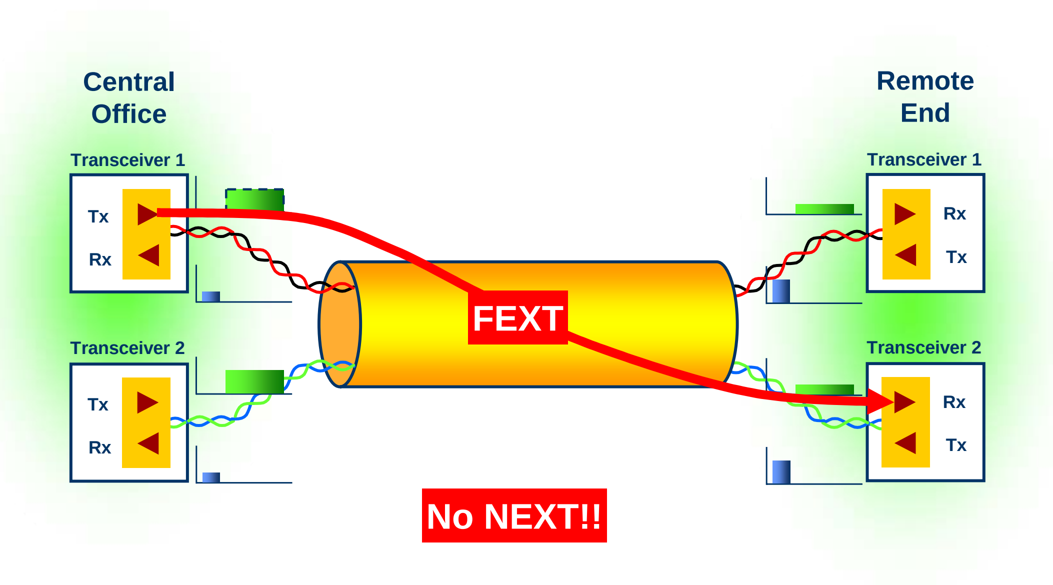
ITU-T G.992.1 Annex B, AoISDN, Non-overlapped spectrum (FDM)



Crosstalk (NEXT and FEXT)



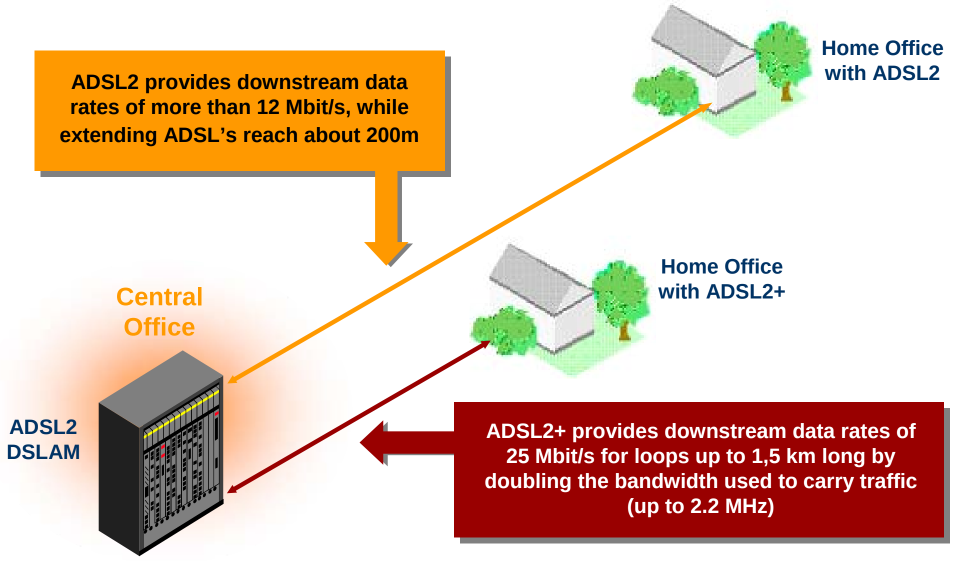
Crosstalk and ADSL



Back

ADSL2 and ADSL2+

The ADSL2 and ADSL2+ standards improve on the original ADSL by offering higher downstream data rates and longer reach



ADSL standards

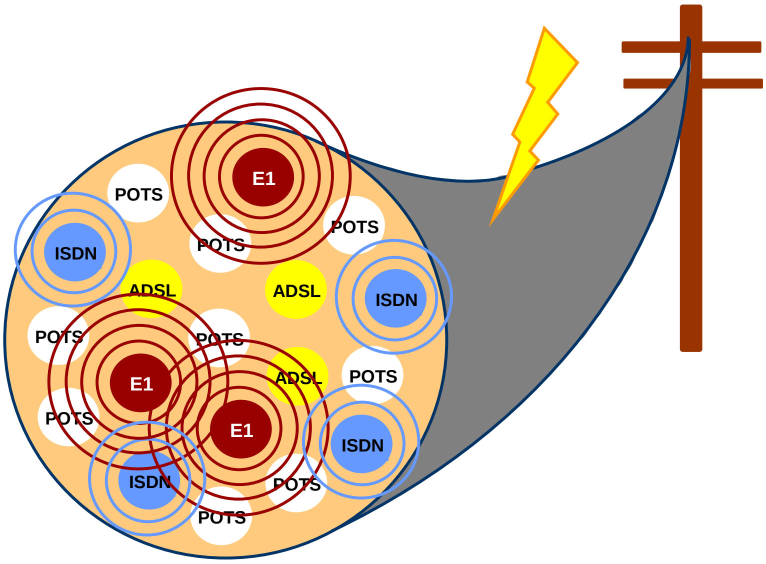
Family	Description	Ratified
ADSL	G.992.1 G.dmt	1999
ADSL	G.992.2 G.lite	1999
ADSL2	G.992.3 G.dmt.bis	2002
ADSL2	G.992.4 G.lite.bis	2002
ADSL2	G.992.5 ADSL2 plus	2003

Back in July 2002, the ITU completed the ADSL2 standards; in January 2003, the completion of ADSL2+ brought unprecedented data rates of 24 Mbps to the ADSL2 standards. And in October 2003, Reach Extended ADSL2 joined the ADSL2 family, delivering bandwidth on phone lines as long as 6.5 km.

This slide provides a summary of ADSL technology standards.

ADSL2 Seamless Rate Adaptation

Addressing problems like crosstalk from adjacent copper pairs



  Dag Hauge – JDSU Nordic

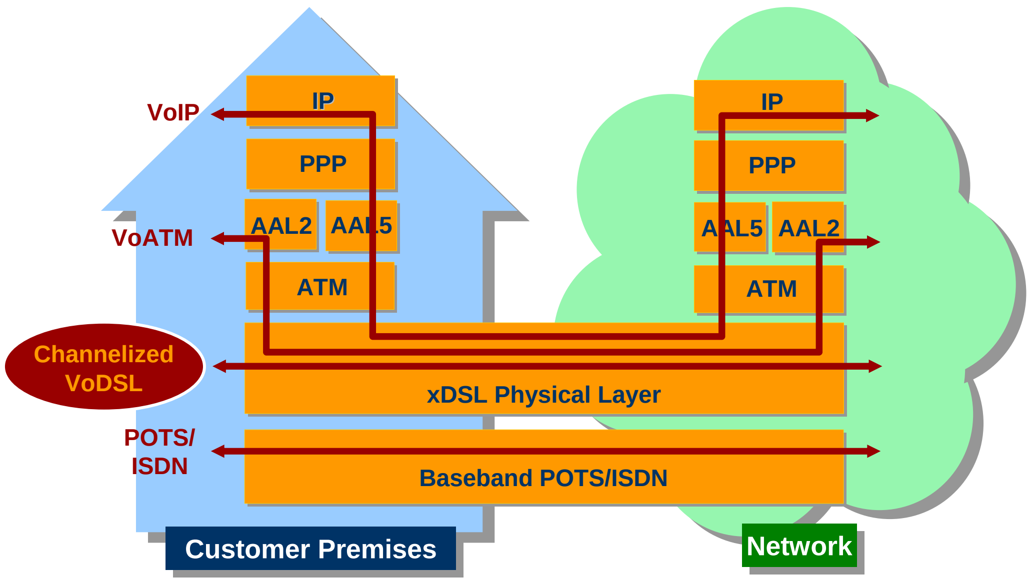
Telephone wires are bundled together in multi-pair binders containing 25 or more twisted wire pairs. As a result, electrical signals from one pair can electromagnetically couple onto adjacent pairs in the binder. This phenomenon is known as "crosstalk" and can impede ADSL data rate performance. As a result, changes in the crosstalk levels in the binder can cause an ADSL system to drop the connection. Crosstalk is just one reason that ADSL lines drop connections. Others include AM radio disturbers, temperature changes, and water in the binder.

ADSL2 addresses these problems by seamlessly adapting the data rate in real-time. This new innovation, called seamless rate adaptation (SRA), enables the ADSL2 system to change the data rate of the connection while in operation without any service interruption or bit errors. ADSL2 simply detects changes in the channel conditions -- for example, a local AM radio station turning off its transmitter for the evening -- and adapts the data rate to the new channel condition transparently to the user.

SRA is based on the decoupling of the modulation layer and the framing layer in ADSL2 systems. This decoupling enables the modulation layer to change the transmission data rate parameters without modifying parameters in the framing layer which would cause the modems to lose frame synchronization resulting in uncorrectable bit errors or system restart. SRA uses the sophisticated online reconfiguration (OLR) procedures of ADSL2 systems to seamlessly change the data rate of the connection. The protocol used for SRA works as follows:

1. The receiver monitors the SNR of the channel and determines that a data rate change is necessary to compensate for changes in channel conditions.
2. The receiver sends a message to the transmitter to initiate a change in data rate. This message contains all necessary transmission parameters for transmitting at the new data rate. These parameters include the number of bits modulated and transmit power on each subchannel in ADSL multi carrier system.
3. The transmitter sends a "Sync Flag" signal which is used as a marker to designate the exact time at which the new data rate and transmission parameters are to be used.
4. The Sync Flag signal is detected by the receiver and both transmitter and receiver seamlessly and transparently transition to the data rate.

CVoDSL vs. VoATM and VoIP

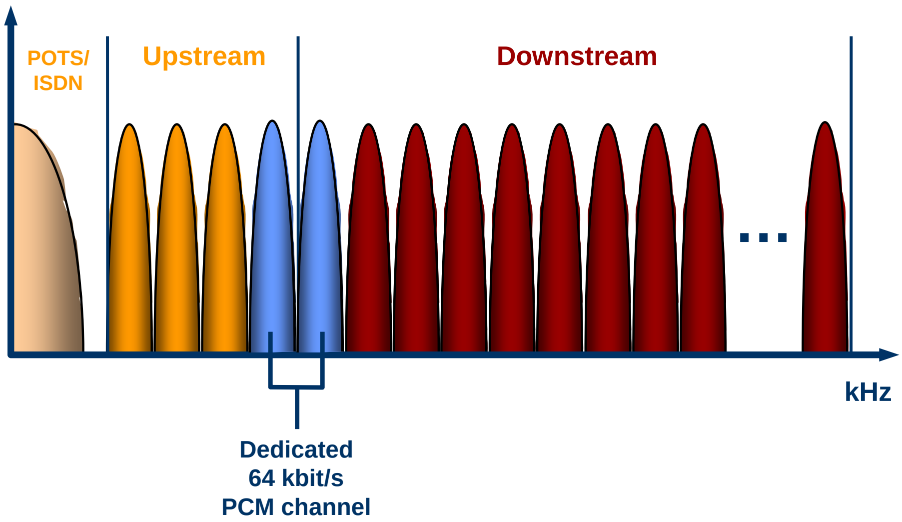


ADSL2 provides the ability to split the bandwidth into different channels with different link characteristics for different applications. For example, ADSL2 enables simultaneous support of a voice application, which might have low latency but a higher error rate requirement, and a data application, which might have high latency but lower error rate requirement.

ADSL2's channelization capability also provides support for Channelized Voice over DSL (CVoDSL), a method to transport derived lines of TDM voice traffic transparently over DSL bandwidths. CVoDSL is unique among voice over DSL solutions in that it transports voice within the physical layer, allowing transport of derived voice channels over DSL bandwidth while maintaining both POTS and high-speed Internet access. The result is a simple, flexible, cost-effective method to enable next-generation equipment with derived voice functionality.

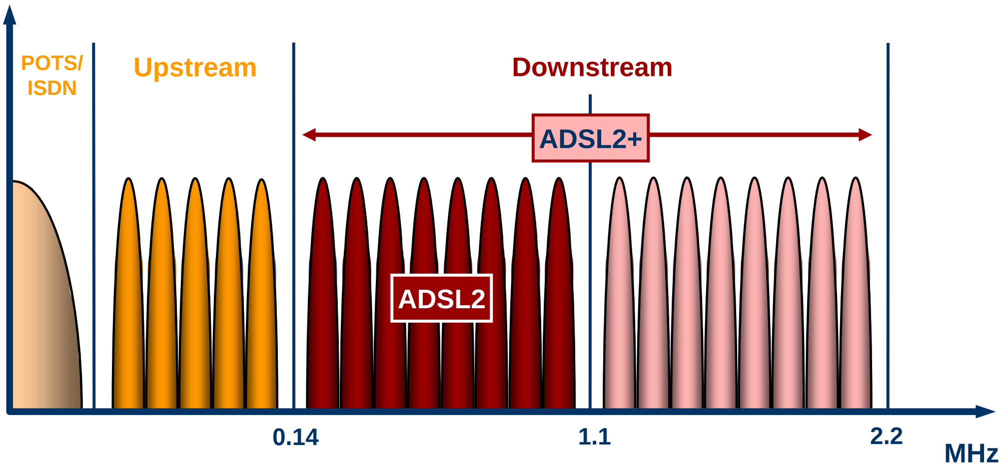
This approach eliminates the need for packetization of voice traffic over the phone line into higher protocols such as ATM and IP. Multiple voice lines can be active simultaneously; given typical constraints on ADSL upstream bandwidth, four uncompressed voice lines might be a reasonable maximum, using an upstream bandwidth of 256 kbps.

CVoDSL



CVoDSL reserves 64 kbps “channels” of DSL bandwidth to deliver PCM DS0s from the DSL modem to the remote terminal or central office, much like regular POTS (plain old telephone service). The access equipment then transmits the voice DS0s directly to the circuit switch via PCM.

ADSL2+ Doubles the Downstream Bandwidth



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ADSL2+ reached consent at the ITU in January 2003, joining the ADSL2 standards family as G.992.5. The ADSL2+ recommendation doubles the downstream bandwidth, thereby increasing the downstream data rate on telephone lines shorter than about 1.5 km. While the first two members of the ADSL2 standards family specify a downstream frequency band up to 1.1 MHz and 552 kHz respectively, ADSL2+ specifies a downstream frequency up to 2.2 MHz.

ADSL Standards Annexes

		USE OF TONES					APPLICABLE TO:		
ANNEX	ENVIRONMENT	1-5	6-31	32-64	65-255	256-512	ADSL G.992.1	ADSL2 G.992.3	ADSL2+ G.992.5
A	POTS	POTS	UP	DOWN	DOWN	DOWN*	YES	YES	YES
B	ISDN	ISDN	ISDN	UP	DOWN	DOWN*	YES	YES	YES
C	TCM-ISDN	POTS	UP	DOWN	DOWN	N/A	YES	YES	YES
I (ADSL)	TCM-ISDN	POTS	UP	DOWN	DOWN	DOWN	YES	NO	NO
I (ADSL2/2+)	POTS	UP	UP	DOWN	DOWN	DOWN*	NO	YES	YES
J	ISDN	UP	UP	UP	DOWN	DOWN*	NO	YES	YES
L (RE-ADSL2)	POTS	POTS	UP**	DOWN**	DOWN**	N/A	NO	YES	NO
M (ADSL2/2+)	POTS	POTS	UP	UP	DOWN	DOWN*	NO	YES	YES

Use of the tones applies to the non-overlapped PSD masks only
* ADSL2+ only
** Not all tones are used

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ADSL standards include annexes that specify ADSL operation for particular applications and regions around the world. Several annexes associated with the first ADSL standard will also apply to the ADSL2 standards family, including ADSL2+. Generally speaking, the annexes specify subcarriers (or tones) and their associated transmission power levels used for upstream and downstream transmission. This slide summarizes the ADSL annexes.

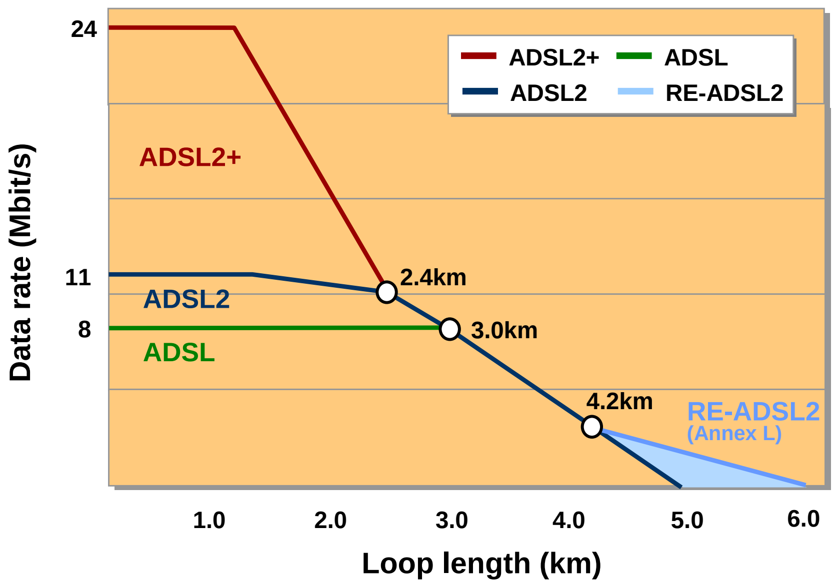
Annexes A and B: Annex A specifies operation of ADSL using bandwidths higher than POTS, so as to preserve POTS operation. It is the most common application of ADSL, used throughout North America and much of Europe and Asia. Annex B works similarly to Annex A, though it is designed to work on phone lines enabled with ISDN instead of POTS, which is common in Germany, Denmark and Norway and a few other regions. Both Annex A and Annex B have been extended to apply to ADSL2 and ADSL2+.

Annexes C and I: Annex C of the original ADSL standards (G.992.1, G.992.2) is designed specifically for use in Japan. It allows ADSL to operate in such a way so as not to interfere with Japan's special "pingpong" version of ISDN, or TCM-ISDN. New features of Annex C were consented by the ITU in January 2003 to improve ADSL technologies used in Japan. A new annex to complement the original ADSL Annex C called "Annex I" doubles the downstream of the original Annex C, much like ADSL2+ doubles the downstream of ADSL2. This particular Annex I will not apply to ADSL2. Note that there are two "Annex I"s; one for the original ADSL, and one for ADSL2/ADSL2+. There is also a separate amendment to ADSL Annex C that improves its reach.

Annexes I and J: Annexes I and J for ADSL2 are for all-digital operation, meaning that traditional voice bandwidths are used by DSL to transmit digital data instead of for traditional voice. Annexes I and J are specified for all-digital operation in POTS and ISDN environments, respectively. Note that this particular Annex I—applicable only to ADSL2 and ADSL2+—is different from the Annex I that amends the original ADSL Annex C standard for use in Japan. Annex I has been approved for ADSL2 and ADSL2+; Annex J has been approved for ADSL2 and has not yet been approved for ADSL2+.

Annex M: A new Annex M (formerly known as Annex L in G.992.5) for G.992.3 (ADSL2) and G.992.5 (ADSL2+) was consented at the October 2003 ITU meeting in Geneva. Annex M contains PSD Masks for new ADSL2 service over POTS that increases the upstream data rates by doubling the number of US tones to 64. As a result, Annex M provides higher upload speeds for users by doubling the upstream data rate (when compared to Annex A) under certain loop and noise conditions.

ADSL2, ADSL2+ and RE-ADSL2 vs. ADSL rate and reach improvement



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This slide shows the performance of each of the ADSL and ADSL2 standards and annexes on given loop lengths. This illustrates the improvement of rate and reach that ASDL2, ADSL2+, and READSL2 offer when compared to ADSL and each other.