ADSL2 AND ADSL2plus –
THE NEW ADSL STANDARDS

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In July 2002, the ITU completed G.992.3 and G.992.4[1], two new standards for ADSL technology collectively called "ADSL2". In January 2003, as users of ADSL chipsets based on the first generation of ADSL standards passed the 30-million mark, G.992.5 officially joined the ADSL2 family as ADSL2plus, (or ADSL2+ as it is commonly known). Several other features and improvements were also incorporated in the form of new Annexes.

Carriers, service providers, and subscribers have played a key role in the completion of ADSL2, having provided valuable feedback from the field that the ITU in turn incorporated into the standards in the form of new features and performance improvements. As a result, ADSL2 will be more user-friendly to subscribers and more profitable to carriers, and promises to continue the great success of ADSL through the rest of the decade.

ADSL2 (ITU G.992.3 and G.992.4) adds new features and functionality targeted at improving performance and interoperability, and adds support for new applications, services, and deployment scenarios. Among the changes are improvements in data rate and reach performance, rate adaptation, diagnostics, and stand-by mode, to name a few.

ADSL2plus (ITU G.992.5) doubles the bandwidth used for downstream data transmission, effectively doubling the maximum downstream data rates, and achieving rates of 20 Mbps on phone lines as long at 5,000 feet. ADSL2plus solutions will most commonly be multimodal, interoperating with ADSL and ADSL2, as well as with ADSL2plus chipsets. More detail about ADSL2plus is included later in this paper.

ADSL2plus will enable service providers to evolve their networks to support advanced services such as video in a flexible way, with a singular solution for both short-loop and long-loop applications. It will include all the feature and performance benefits of ADSL2 while maintaining the capability to interoperate with legacy equipment. As such, carriers will be able to overlay new, advanced technologies without having to "forklift-upgrade" existing equipment, allowing for a gradual transition to advanced services.

Rate and Reach Improvements

ADSL2 has been specifically designed to improve the rate and reach of ADSL largely by achieving better performance on long lines in the presence of narrowband interference. ADSL2 achieves downstream and upstream data rates of about 12 Mbps and 1 Mbps respectively, depending on loop length and other factors. ADSL2 accomplishes this by improving modulation efficiency, reducing framing overhead, achieving higher coding gain, improving the initialization state machine, and providing enhanced signal processing algorithms. As a result, ADSL2 mandates higher performance for all standard-compliant devices.

ADSL2 provides better modulation efficiency by mandating four-dimensional, 16-state trellis-coded and 1-bit quadrature amplitude modulation (QAM) constellations, which provide higher data rates on long lines where the signal-to-noise ratio (SNR) is low. In addition, receiver-determined tone reordering enables the receiver to spread out the non-stationary noise due to AM radio interference to get better coding gain from the Viterbi decoder.

ADSL2 systems reduce framing overhead by providing a frame with a programmable number of overhead bits. Therefore, unlike the first-generation ADSL standards where the overhead bits per frame are fixed and consume 32 kbps of actual payload data, in the ADSL2 standard the overhead bits per frame can be programmed from 4 to 32 kbps. In first-generation ADSL systems, on long lines where the data rate is low (e.g. 128 kbps), a fixed 32 kbps (or 25% of the total data rate) is allocated to overhead information. In ADSL2 systems, the overhead data rate can be reduced to 4 kbps, which provides an additional 28 kbps for payload data.

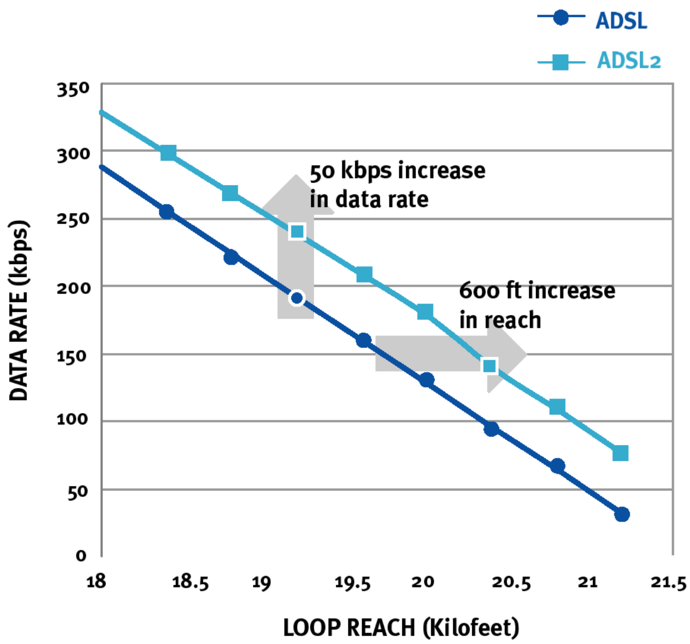
On long lines where data rates are lower, ADSL2 achieves higher coding gain from the Reed-Solomon (RS) code. This is due to improvements in the ADSL2 framers that improve flexibility and programmability in the construction of the RS codewords.

Additionally, the initialization state machine has numerous improvements that provide increased data rates in ADSL2 systems. Examples include:

- Power cutback capabilities at both ends of the line to reduce near-end echo and the overall crosstalk levels in the binder.
- Determination of the pilot tone location by the receiver in order to avoid channel nulls from bridged taps or narrow band interference from AM radio.
- Control of certain key initialization state lengths by the receiver and transmitter in order to allow optimum training of receiver and transmitter signal processing functions.
- Determination of the carriers used for initialization messages by the receiver in order to avoid channel nulls from bridged taps or narrow band interference from AM radio.
- Improvement in channel identification for training receiver time domain equalizer with spectral shaping during Channel Discovery and Transceiver Training phases of initialization.
- Tone blackout (disabling tones) during initialization to enable radio frequency interference (RFI) cancellation schemes.

Figure 1 shows the rate and reach of ADSL2 as compared to the first-generation ADSL standard. On longer phone lines, ADSL2 will provide a data rate increase of 50 kbps for upstream and downstream; a significant increase for those customers who need it most. This data rate increase results in an increase in reach of about 600 feet, which translates to an increase in coverage area of about 6%, or 2.5 square miles.

Figure 1: ADSL2 systems can deliver an improvement in reach of about 600 feet.



Diagnostics

Determining the cause of problems in consumer ADSL service has at times been a challenging obstacle in ADSL deployments. To tackle the problem, ADSL2 transceivers have been enhanced with extensive diagnostic capabilities. These diagnostic capabilities provide tools for trouble resolution during and after installation, performance monitoring while in service, and upgrade qualification.

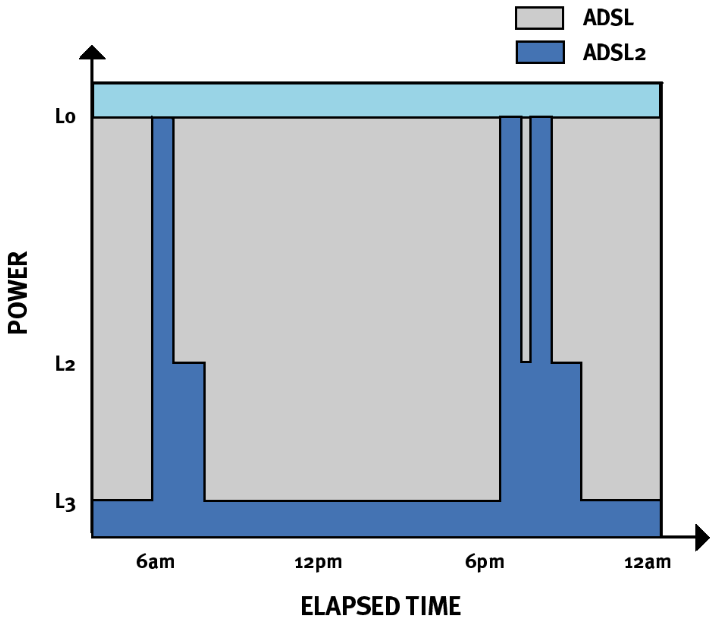
In order to diagnose and fix problems, ADSL2 transceivers provide for measurements of line noise, loop attenuation, and signal-to-noise ratio (SNR) at both ends of the line. These measurements can be collected using a special diagnostic testing mode even when line quality is too poor to actually complete the ADSL connection.

Additionally, ADSL2 includes real-time performance monitoring capabilities that provide information on line quality and noise conditions at both ends of the line. This information is interpreted by software and then used by the service provider to monitor the quality of the ADSL connection and prevent future service failures. It can also be used to determine if a customer can be offered higher data rate services.

Power Enhancements

First-generation ADSL transceivers operate in full-power mode day and night, even when not in use. With several millions of deployed ADSL modems, a significant amount of electricity can be saved if the modems engage in a standby/sleep mode just like computers. This would also save power for ADSL transceivers operating in small remote units and digital loop carrier (DLC) cabinets that operate under very strict heat dissipation requirements (Figure 2). To address these concerns, the ADSL2 standard brings in two power management modes that help reduce overall power consumption while maintaining ADSL's "always-on" functionality for the user. These modes include:

Figure 2: ADSL2's L2 power mode allows a broadband modem to quickly move from L2 to L0 operation and back without bit errors.



L2 low-power mode

This mode enables statistical powers savings at the ADSL transceiver unit in the central office (ATU-C) by rapidly entering and exiting low power mode based on Internet traffic running over the ADSL connection.

L3 low-power mode

This mode enables overall power savings at both the ATUC and the remote ADSL transceiver unit (ATU-R) by entering into sleep mode when the connection is not being used for extended periods of time.

The L2 power mode is one of the most important innovations of the ADSL2 standard. ADSL2 transceivers can enter and exit the L2 low power mode based on the Internet traffic over the ADSL connection. When large files are being downloaded, ADSL2 operates in full power mode (called "L0" power mode) in order to maximize the download speed. When Internet traffic decreases, such as when a user is reading a long text page, ADSL2 systems can transition into L2 low power mode, in which the data rate is significantly decreased and overall power consumption is reduced.

While in L2, the ADSL2 system can instantly re-enter L0 and increase to the maximum data rate as soon the user initiates a file download. The L2 entry/exit mechanisms and resulting data rate adaptations are accomplished without any service interruption or even a single bit error, and as such, are not noticed by the user.

The L3 power mode is a sleep mode where no traffic can be communicated over the ADSL connection when the user is not online. When the user returns to go on-line the ADSL transceivers require approximately three seconds to re-initialize and enter into steady-state communication mode.

Rate Adaptation

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 electro-magnetically couple

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