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VDSL2
A feasible Solution for “Last Mile”

Talking to the Future

ZTE中兴

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1 Brief Introduction of VDSL2

ADSL2plus is currently being deployed worldwide as the new mainstream broadband technology for residential and business customers. But at the same time, the industry is gearing up for the next step of the DSL evolution: VDSL2. This second version of the very high-speed digital subscriber line (VDSL) standard from ITU-T promises to deliver 100Mbps symmetrical traffic on short copper loops. The greater bandwidth of VDSL2 gives telecommunications operators the ability to offer advanced services such as multiple streams of interactive standard and high-definition TV over IP over the existing copper plant. TV services are fast becoming strategically important to telecommunication operators who are competing head-to-head with cable operators launching voice over IP (VoIP) and high-speed internet services.

ITU began drafting its VDSL2 standard (G.993.2) in January 2004. Consensus for the standard was reached at a meeting in Geneva in May 2005. As with ADSL/2/plus, the underlying modulation in the VDSL2 standard is discrete multitone (DMT). VDSL2 is based on both the VDSL1-DMT and ADSL2/ADSL2plus recommendations. Therefore, it is spectrally compatible with existing services and enables multimode operability with ADSL/2/plus. VDSL2 extend the spectrum to 30MHz and can deliver 200Mbps symmetrical traffic on short copper loops at most.

2 VDSL2 Standard

2.1 ITU-T G.993.1

ITU-T G.993.1 VDSL (very high-speed digital subscriber line) standard, defined the first generation VDSL system model, interface requirements, performance requirements, management requirements, power supply requirements, security requirements and transceiver technical requirements. This version of the very high-speed digital subscriber line (VDSL) standard from ITU-T promises to deliver 55Mbps downstream bandwidth and 19.2Mbps upstream bandwidth on short copper loops.

2.2 ITU-T G.993.2

VDSL2 enhanced ITU-T G.993.1 VDSL technology, which supports 100Mbps symmetrical bandwidth on short copper loops. VDSL2 defined DMT modulation technology, and made it possible that provide reliable high speed data transmission on short copper loops by use 30MHz spectrum band. VDSL2 supports Trellis Coded forcibly, and adopts US0 band, Echo Canceller, and Time equalizers (TEQs), so VDSL2 can work stably on about 2500m length 26AWG copper loops (0.4mm).

G.993.2 defined all the parameters which VDSL2 transceiver maybe supports (such as bandwidth and transceiver power). Otherwise, G.993.2 also defined many items which make vendors can reduce complexity of products and develop suitable solutions for real services requirement. Some items are suit for symmetrical data speed services; others are for asymmetrical data speed services.

G.993.2 accessory includes band planning and power spectrum density (PSD), and defined regional special requirements.

Compare with ITU-T G.993.1, G.993.2 has the following changes:

- Carrier frequency up to 30 MHz, bidirectional data speed up to 200 Mbit/s;
- Extend the upper limit of US0 band to 276 kHz;
- Echo canceller and time equalizers (TEQs) are used to improve US0 performance;
- Widely application scenarios (CO, Cabinet, Building, etc.);
- Downstream transmission power up to 20.5 dBm;
- Supports Trellis Coded forcibly;
- Supports all integral constellations from 1bit to 15bit;
- Supports random cycled extension;
- Supports all integral impulse noise protection (INP) which can have 16 characters at most;
- Enhanced online reconfiguration (OLR);
- Enhanced framing function;
- Enhanced overhead channel;
- Enhanced interlacing;
- Enhanced FEC function;
- Defined two waiting time paths and two bearer channels;
- Improved initialization process, include channel discovery phase, training phase, channel analysis and switching phase;
- Supports VTU-R during initialization phase;
- Supports abundant testing parameters;
- Defined loop diagnosis mode;
- Supports STM interface;
- Supports PTM interface which base on IEEE 802.3 ah 64/65 byte package.

2.3 ITU-T G.994.1

G.994.1 is the common handshaking or activation procedure for DSL modems. It is fully interoperable with the activation procedure for T1.413 DSL modems but offers several benefits for service providers: robustness, exchange of capabilities information, notification of the application and service requests, backwards and forwards compatibility for other DSL modem standards, etc.

Previous generation DSL modems relied on single tones to negotiate the modem operating options during startup. With G.994.1, simultaneous multiple redundant sets of tones are modulated with digital information. If one or more tones are blocked by interfering noise, bridge taps or otherwise unavailable, at least one will be available to complete the startup information exchange. The tones were selected and the procedures were designed to be compatible with the many other existing services including other DSLs in the network.

The digital information carried by G.994.1 can now go beyond the simple selection of options in previous generation DSL modem startup procedures. Higher layers on each end of the DSL modems can indicate service and application requirements during the handshake so that the appropriate DSL Recommendation from the family of DSL recommendations will be activated following the G.994.1 handshake. This allows providers to flexibly tailor the service bandwidth and latency requirements of the customer's dynamic applications and environments including mobile DSL modems or modem pooling. The G.994.1 data architecture is flexible enough to allow exchange of new or non-standard information without upgrading the installed software base.

2.4 Broadband Forum TR-129

TR-129 is defined by Broadband forum, DSL forum has renamed to Broadband forum. TR-129 management model suits for ADSL, ADSL2, ADSL2+, VDSL2 technologies.

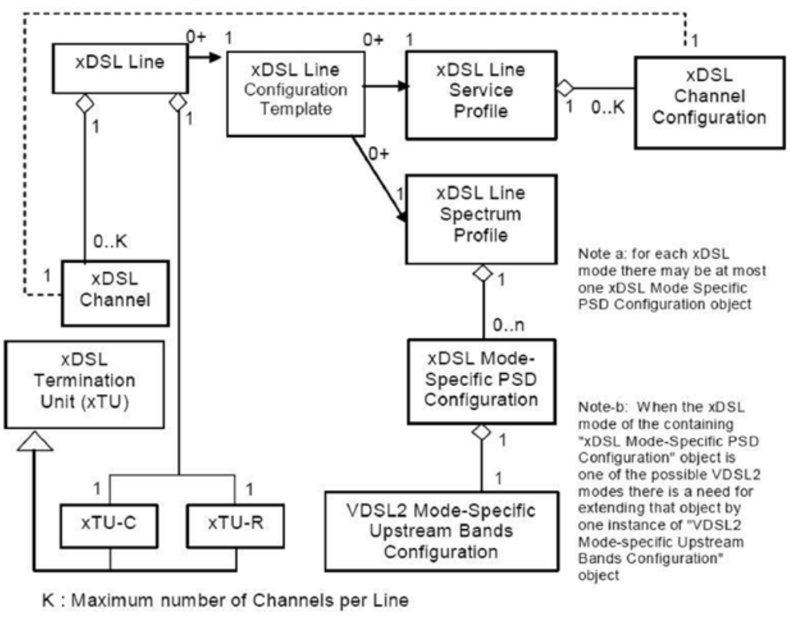

Figure 1 TR-129 Management Model

2.5 Broadband Forum TR-165

TR-165 is Vector of Profile standard which defined by Broadband forum. TR-165 was improved base on TR-129 to make management easier.

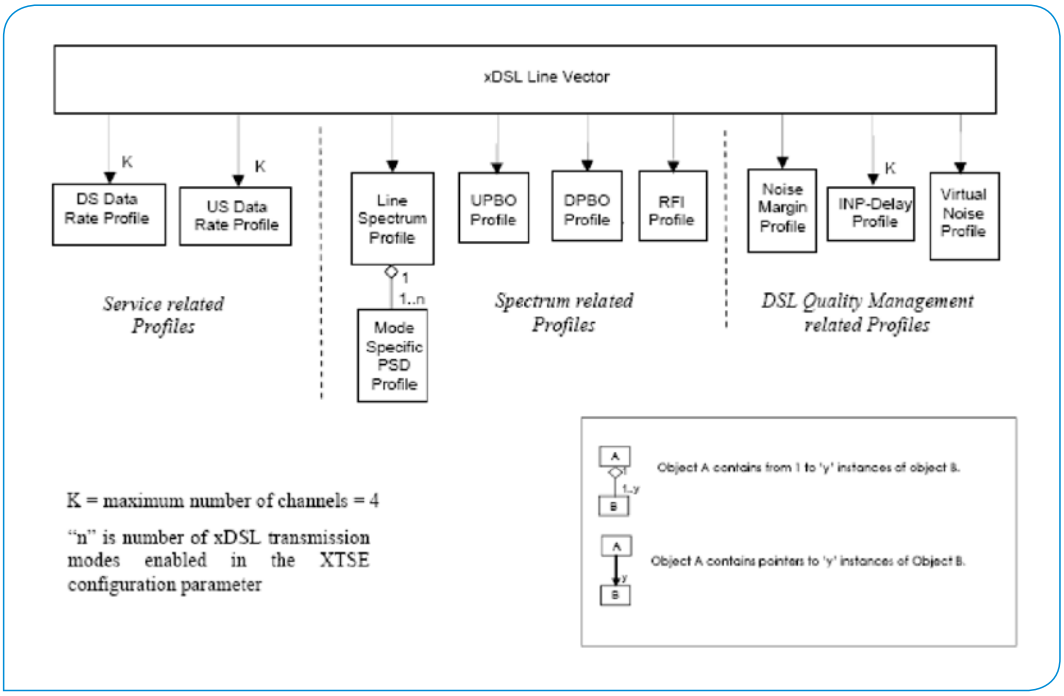

Figure 2 Vector of Profile Model

3 VDSL2 Technology

3.1 VDSL2 Profiles

G.993.2 defines a wide range of settings for various parameters that could potentially be supported by a VDSL2 transceiver. Profiles are specified to allow transceivers to support a subset of the allowed settings. The specification of multiple profiles allows vendors to limit implementation complexity and develop implementations that target specific service requirements.

VDSL2 transceivers shall comply with at least one profile specified in G.993.2. Compliance with more than one profile is allowed. In addition to complying with at least one profile, VDSL2 transceivers shall comply with at least one annex specifying spectral characteristics.

The eight VDSL2 profiles (8a, 8b, 8c, 8d, 12a, 12b, 17a, and 30a) are defined in Table 1.

Table 1 VDSL2 Profiles

Profile	8a	8b	8c	8c	12a	12b	17a	30a
Bandwidth(kHz)	8,832	8,832	8,832	8,832	12,000	12,000	17,664	30,000
Sub channel	2048	2048	2048	2048	2783	2783	4096	3479
Sub channel Spacing(kHz）	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	8.625
Minimum bi-direction net data rate capacibility	50Mbps	50Mbps	50Mbps	50Mbps	68Mbps	68Mbps	100Mbps	200Mbps
Aggregate interleaver and de-interleaver delay (octets)	64k	64k	64k	64k	64k	64k	96k	128k
Maximum interleaving (octets)	2048	2048	2048	2048	2048	2048	3072	4096
Parameter (1/S)max downstream	24	24	24	24	24	24	48	28
Parameter (1/S)max upstream	12	12	12	12	12	24	24	28
Support of US0	YES	YES	YES	YES	YES	NO	NO	NO
DS/US Power （dbm）	+17.5 /+14.5	+20.5 /+14.5	+11.5 /+14.5	+14.5 /+14.5	+14.5 /+14.5	+14.5 /+14.5	+14.5 /+14.5	+14.5 /+14.5

3.2 DMT Modulation

DMT modulation uses the same principle as orthogonal frequency-division multiplexing (OFDM).6 That is, it divides the useful frequency spectra into parallel channels, where the center of each channel is represented by a modulated (QAM) subcarrier (Figure 3). One difference from OFDM is that each carrier in DMT can be loaded with a different number of bits, depending on the signal to noise ratio (SNR). In OFDM, the constellation size of each carrier is the same. Because each subcarrier is orthogonal to the other subcarriers, there is no interference between subcarriers. The number of bits can be varied between 1 and 15. The distance between subcarriers is 4.3125kHz. In VDSL2 a distance of 8.6125kHz may also be used. Inverse fast Fourier transform (IFFT) is used to generate the subcarriers.

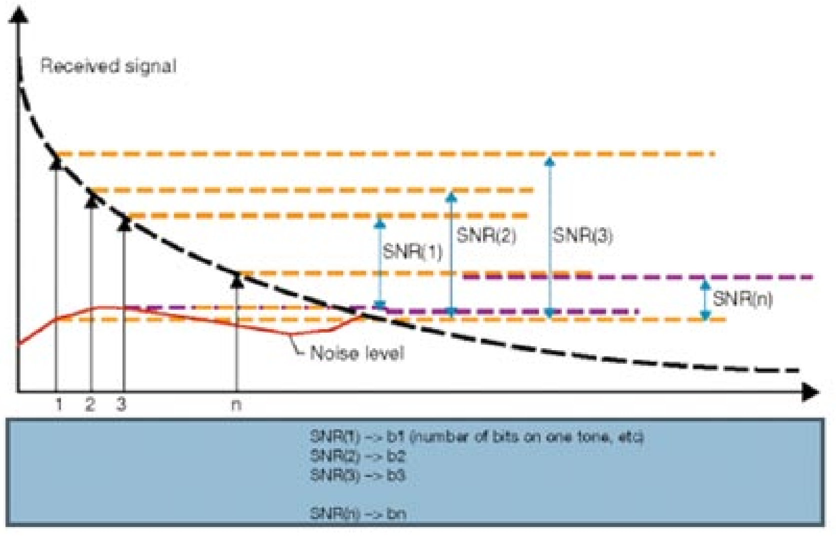

Figure 3 Discrete Multitone(DMT)

3.3 Band Plans

ADSL can be described as a two-band system where one part of the frequency spectrum is used for upstream transmission and the second part is used for downstream transmission (Figure 4). VDSL, on the other hand, uses multiple bands for upstream and downstream transmissions to enable a greater degree of flexibility with regards to rate configurations and symmetry between upstream and downstream data.

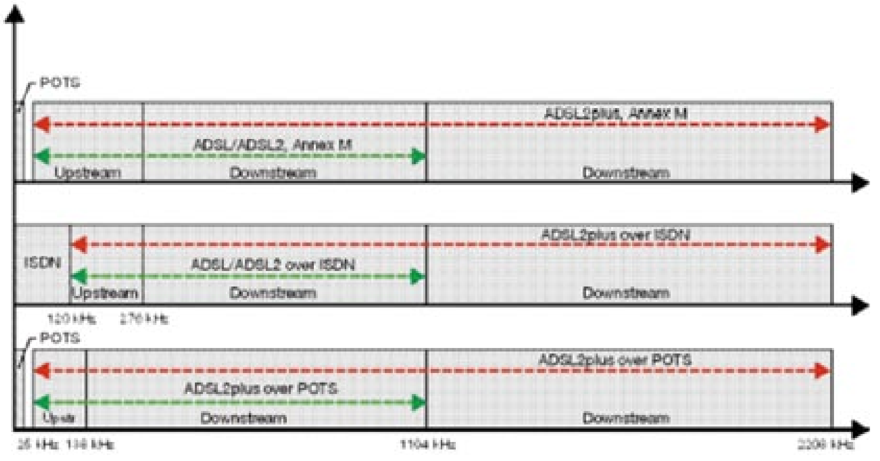

Figure 4 ADSL/ADSL2/ADSL2+ Frequency Allocation

Two band plans were defined (in 2000) to meet operator requirements for symmetry/ asymmetry (Figure 5). The first of these, Band Plan 998, better facilitates asymmetric services, whereas Band Plan 997 accommodates symmetric services. VDSL1 supports a bandwidth of up to 12MHz; in VDSL2 this can be extended to 30MHz. To be spectrally compatible with VDSL1, VDSL2 uses the same band plans below 12MHz. VDSL2 can employ up to 4,096 subcarriers. Depending on the band plan in use, a subcarrier is designated for either upstream transmission or downstream transmission. As in ADSL, the lower part of the spectra is allocated for POTS and ISDN service and a splitter filter is used to separate the POTS or ISDN frequencies from the VDSL2 band. An "all digital modes" option also exists, where virtually all the spectra can be used for VDSL2.

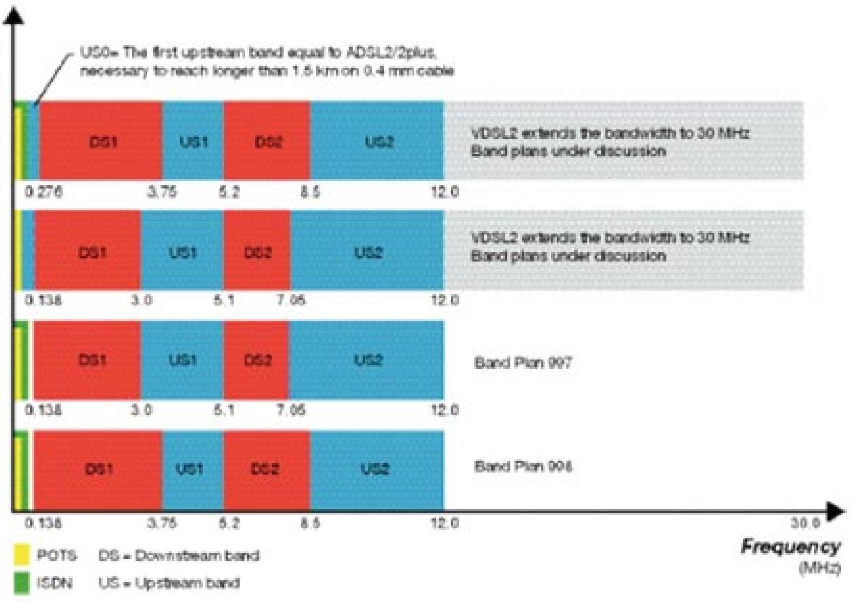

Figure 5 Band Plans of VDSL1 and VDSL2

3.4 Duplexing

Today deployments of ADSL/2/plus use frequency-division duplex (FDD) technology to separate the upstream band from the downstream band. Given the physical properties, however, it is not possible to create a "brick wall" transmission band. That is, there is always some spectral leakage between the transmission bands. In ADSL, filters or echo cancellers are used to suppress leakage between transmission bands. VDSL, on the other hand, uses a digital duplexing technique based on the "zipper" technology invented at Telia Research in Luleå.7 With this technique, adjacent sub carriers carry data in opposite directions (Figure 6).

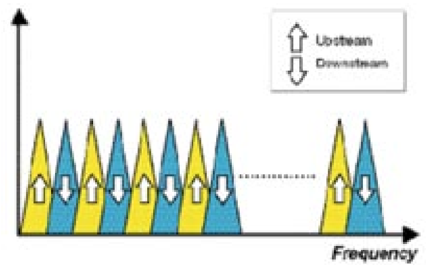

Figure 6 The "Zipper" Principle

However, requirements for spectral compatibility with existing DSL technologies require necessitate that several tones must be grouped into transmission bands. One can preserve the orthogonally between the received signal and the transmitted signal echoed back into the receiver by cyclically extending the transmitted DMT symbols using a cyclic prefix and cyclic suffix and by synchronizing the transmitters at each end to begin transmitting at the same time (a technique called timing advance). Cyclic extension, which eliminates inter symbol interference (ISI) caused by the channel, reduces the data rate by 7.8%. Windowing, a technique for suppressing side lobes, further reduces spectral leakage between transmission bands. Windowing is also used in OFDM (Figure 7).

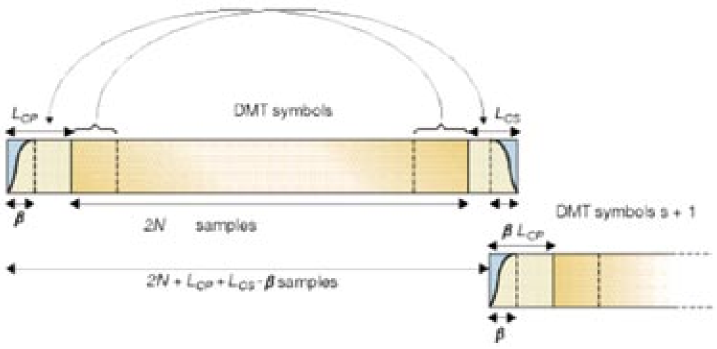

Figure 7 Cyclic Extension

4 VDSL2 Deployment Modes

The VDSL2 standard is defined using sets of profiles, where each profile target a specific deployment. Figure 8 depicts the different deployment scenarios anticipated for VDSL2. These include:

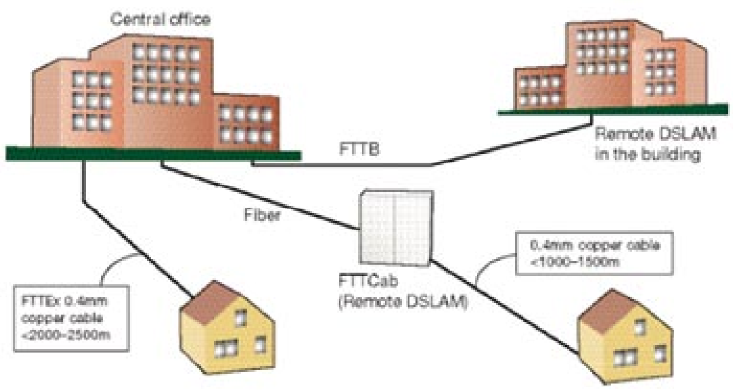

Figure 8 VDSL2 Deployment Scenarios

- Fiber to the Node (FTTN): VDSL2 is located at the central office;
- Fiber to the cabinet (FTTCab): fiber-fed cabinets are located near customer premises;
- Fiber to the building (FTTB): VDSL2 is placed, for instance, in the basement of a building.

Profiles 8a-8b and 12a-12b apply to FTTN; 17a applies to FTTCab; and 30a, to FTTB (Figure 9). Each profile contains support for underlying base band services, such as POTS or ISDN.

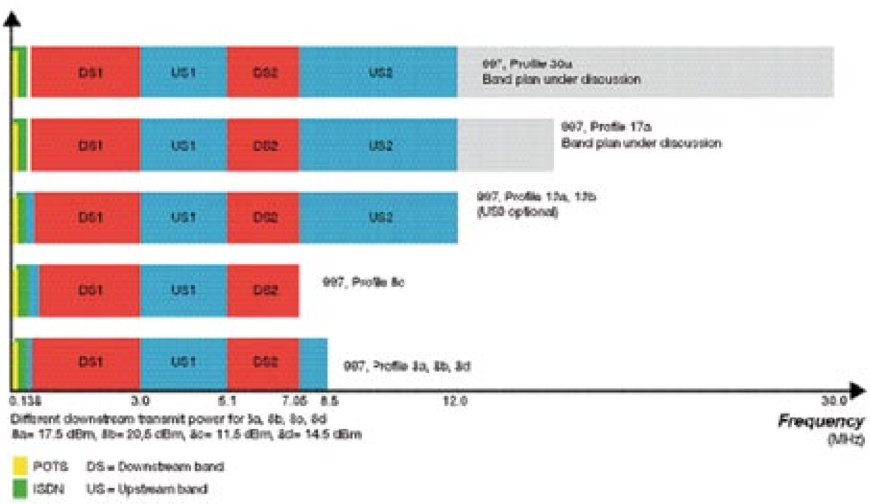

Figure 9 VDSL2 Profiles for Different Deployment Mode

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