DSL Technology Evolution

ADSL2/ADSL2plus/ADSL-RE/VDSL2
Today there are various DSL Technology Options

<table>
<thead>
<tr>
<th>Family</th>
<th>ITU</th>
<th>Name</th>
<th>Ratified</th>
<th>Maximum Speed capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSL</td>
<td>G.992.1</td>
<td>G.dmt</td>
<td>1999</td>
<td>7 Mbps down 800 kbps up</td>
</tr>
<tr>
<td>ADSL2</td>
<td>G.992.3</td>
<td>G.dmt.bis</td>
<td>2002</td>
<td>8 Mb/s down 1 Mbps up</td>
</tr>
<tr>
<td>ADSL2plus</td>
<td>G.992.5</td>
<td>ADSL2plus</td>
<td>2003</td>
<td>24 Mbps down 1 Mbps up</td>
</tr>
<tr>
<td>ADSL2-RE</td>
<td>G.992.3</td>
<td>Reach Extended</td>
<td>2003</td>
<td>8 Mbps down 1 Mbps up</td>
</tr>
<tr>
<td>SHDSL (updated 2003)</td>
<td>G.991.2</td>
<td>G.SHDSL</td>
<td>2003</td>
<td>5.6 Mbps up/down</td>
</tr>
<tr>
<td>VDSL</td>
<td>G.993.1</td>
<td>Very-high-data-rate DSL</td>
<td>2004</td>
<td>55 Mbps down 15 Mbps up</td>
</tr>
<tr>
<td>VDSL2 - 12 MHz long reach</td>
<td>G.993.2</td>
<td>Very-high-data-rate DSL 2</td>
<td>2005</td>
<td>55 Mbps down 30 Mbps up</td>
</tr>
<tr>
<td>VDSL2 - 30 MHz Short reach</td>
<td>G.993.2</td>
<td>Very-high-data-rate DSL 2</td>
<td>2005</td>
<td>100 Mbps up/down</td>
</tr>
</tbody>
</table>
Market Status of DSL Technology

- **DSL is the #1 Broadband Choice in the World with over 65% marketshare and more than 200 million users**
- **DSL is available in every region of the world, and ADSL owns the majority of the market though VDSL and ADSL2plus are gaining ground**
- **DSL is capable of providing up to 100 Mbp, and supports voice, video and data.**
- **The new DSL network is IP-centric**
- **There is broad equipment interoperability and there are currently established test specifications for ADSL, ADSL2plus, SHDSL, and soon VDSL2 will join the list**
- **Finally, ADSL and home networking are a natural fit as DSL effectively supports multiple applications for multiple uses via each DSL connection.**
DSL Applications

- Internet Access & File Sharing
- Video
  - Broadcast TV
  - Video On Demand
  - User generated video
- Telecommuting
- Online Education & Shopping
- Telemedicine
- Online Gaming
How Does DSL Work?

- Functional Elements
- Use of Bandwidth
- Channel Separation & POTS Splitter
- New IP-centric Architecture
Simple overview of ADSL in the phone network

POTS- Plain Old Telephone Service
All the elements
TR-059 specifies IP Routed Network Architecture to support a mix of IP based services including IP Video from an Application Service Provider, by employing DiffServ.
TR-101 Reference Model

Access Aggregation Moves from ATM to IP Ethernet

NSP – Network Service Provider
ASP – Application Service Provider
Latest Developments

What each DSL flavor offers
SHDSL Option

- Not widely used in the industry
- G.shdsl (G.991.2)
  - ITU Recommendation
    1st Global Standard for DSL after ADSL
    Harmonized w/ ETSI SDSL & ANSI HDSL2
  - Two-wire Operation
    Symmetrical and Rate Adaptive
    192kbps to 2.312Mbps
  - Options to the Standard
    4-wire operation
    Repeaters
    Fixed rate operation at 784 kb/s and 1.544 kb/s
Latest options gaining ground

- **ADSL2**
  - Approved by ITU-T as G.992.3 July 2002
  - Features
    - Improved rate – up to 12Mbps by 1Mbps
    - Improved reach – around 600ft / 180m
      - Power cutback capability
      - Reduced framing overhead
      - Better modulation efficiency
      - Channelisation capability
      - Bonding of lines
Strong deployment ongoing

- ADSL2plus
  - Approved by ITU-T as G.992.5 January 2003
  - Features
    - Much increased rates – up to 20Mbps by 1Mbps
      - Doubled downstream frequency band to 2.2Mhz
    - Reduced cross talk
    - Allows provision of advanced services
    - Builds on all ADSL2 features
    - Legacy interoperable
Service Migration

- **ADSL2plus**
  - Backward interoperable
  - Services now available
  - Being installed as the “standard” modem chip set
  - Interoperability problems effectively overcome

- **VDSL2**
  - ADSL, ADSL2 and ADSL2plus interoperable
  - Services now available
Better support of new applications

- Triple / Quad play is becoming a reality!
  - ADSL2plus and VDSL2 both offer wide area 20+Mbps multi-channel speeds
    - Allows FTTC and direct from exchange service
    - Full service residential 50Mbps by 10Mbps – max
    - Wide area business Ethernet
    - Feeder transport to remote nodes – using bonding
    - 3 x HDTV (VDSL2), Internet, voice, gaming etc
Network Scalability

- ADSL2plus and VDSL2
  - With VDSL2 now approved:
    - Backward compatible with ADSL2plus etc
    - Offers highly scalable networks
    - Creates new flexibility for service providers
    - Steadily take fibre closer to the subscriber
      - Migrate ADSL → ADSL2plus → VDSL2
    - Easily implemented service expansion and upgrade
Standards evolution empower Video delivery at higher speeds

- **Next Generation ADSL**: ADSL2 (G.992.3)
  - performance improvement (+100 kb/s on average)
  - improved interop, loop diagnostics, robustness
  - improved initialization & fast start-up
  - power management

- **ADSL2plus**: (G.992.5)
  - downstream bandwidth boost up to 24.5 Mb/s

- **Reach Extended ADSL**: RE-ADSL2 (G.992.3 annex L)
  - loop reach increase of 600 to 900 m at low rates (192 kb/s DS + 96 kb/s US)

- **Double upstream**: (G.992.3/5 annex M)
  - double upstream bandwidth

- **Very high speed DSL**
  - bandwidths up to 100 Mb/s on short loops
  - different band plans
    - Plan 997: compromise band plan for symmetric and asymmetric traffic
    - Plan 998: optimized for asymmetry
    - Plan Fx: flexible band plan

Most service providers update with a triple pack: ADSL2, ADSL2plus and RE-ADSL at the same time
Or go straight to VDSL2
Existing High Speed Technologies Did Not Solve the Problem of Bottlenecks

Data rate [Mbit/s]

- **VDSL2** = VDSL Speeds with ADSL/2+ Reach and Flexibility
- Design only for short loop applications (MDU/MTU)
- Real bit-rates are too low for multiple (3) HDTV channels
- Low bit-rates are insufficient for Triple-Play applications

<table>
<thead>
<tr>
<th>Data Rate (Mbit/s)</th>
<th>Line Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>
VDSL2 Standardization

- VDSL2 standardization started in January 2004
- Main technology development in ITU-T
- North American system requirements in ANSI/NIPNAI
- European system requirements in ETSI
- Reached consent in May 2005 (Geneva Meeting)
VDSL2 Key Features

- **DMT modulation**
  - Same as ADSL
  - Bandwidth increased from 12 MHz to 30 MHz
  - Up to 4096 tones (8x ADSL2plus!)

- **Worldwide Versatile Standard**
  - 8 profiles defined for different services
  - Different bandplans for the regions
  - Variety of PSDs to optimize spectral compatibility

- **Support for a variety of services**
  - Integrated Quality of Service features
  - ATM as well as Ethernet payload
  - Channel bonding for extended reach or rate
### VDSL2 - All The Benefits of ADSL2/2plus, Higher Speeds Than VDSL1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>VDSL1</th>
<th>VDSL2</th>
<th>VDSL2 Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bandwidth</strong></td>
<td>VDSL1: 12MHz</td>
<td>VDSL2: 30MHz</td>
<td>Much higher performance for short loops</td>
</tr>
<tr>
<td></td>
<td>VDSL2: None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trellis, SRA, GCI</strong></td>
<td>VDSL1: None</td>
<td>VDSL2: Mandatory</td>
<td>Improved performance</td>
</tr>
<tr>
<td></td>
<td>VDSL2: None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Long Reach</strong></td>
<td>VDSL1: 1km</td>
<td>VDSL2: 3km ...</td>
<td>90% customer reach + single technology</td>
</tr>
<tr>
<td></td>
<td>VDSL2: None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ADSL Compatibility</strong></td>
<td>VDSL1: None</td>
<td>ADSL, ADSL2, ADSL2plus</td>
<td>Reuse existing ADSL infrastructure</td>
</tr>
<tr>
<td></td>
<td>VDSL2: None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quality Of Service (QoS)</strong></td>
<td>VDSL1: None</td>
<td>VDSL2: Dual Latency, Dual Bearer, Pre-Emption</td>
<td>Enable Triple – Play applications</td>
</tr>
</tbody>
</table>
VDSL2 Performance

- Symmetrical 100Mbit/s due to 30MHz bandwidth
- Improved mid range performance through Trellis/Viterbi coding and Generic Convolutional Interleaver
- ADSL-like long reach performance due to Trellis coding and Echo Cancellation

* Numbers are rounded
VDSL2 Standard – Profiles

- **VDSL2 8b**
  - Tx Power: 20.5 dBm
  - Analog Bandwidth: 1.1 MHz
  - DSP Power: 2.2 MHz
  - # of Tones: 256
  - 4 kBaud

- **VDSL2 8a**
  - Tx Power: 17.5 dBm
  - Analog Bandwidth: 8.8 MHz
  - DSP Power: 12.0 MHz
  - # of Tones: 512
  - 4 kBaud

- **VDSL2 8d**
  - Tx Power: 14.5 dBm
  - Analog Bandwidth: 12.0 MHz
  - DSP Power: 17.6 MHz
  - # of Tones: 2048
  - 4 kBaud

- **VDSL2 8c**
  - Tx Power: 11.5 dBm
  - Analog Bandwidth: 17.6 MHz
  - DSP Power: 30.0 MHz
  - # of Tones: 3478
  - 8 kBaud

- **VDSL2 12a,b**
  - Analog Bandwidth: 30.0 MHz

- **VDSL2 17a**

- **VDSL2 30a**

- **No US0**

- **w/ US0**
Bandplans, Annexes, PSDs

<table>
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<tr>
<th>Annex</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex A: ADL</td>
<td></td>
</tr>
<tr>
<td>Annex A: POTS</td>
<td></td>
</tr>
<tr>
<td>Annex B: 997 A</td>
<td></td>
</tr>
<tr>
<td>Annex B: 997 M</td>
<td></td>
</tr>
<tr>
<td>Annex B: 997 B</td>
<td></td>
</tr>
<tr>
<td>Annex B: 998 A</td>
<td></td>
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<tr>
<td>Annex B: 998 M</td>
<td></td>
</tr>
<tr>
<td>Annex B: 998 B</td>
<td></td>
</tr>
<tr>
<td>Annex B: 998 0</td>
<td></td>
</tr>
<tr>
<td>Annex C</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td></td>
</tr>
</tbody>
</table>

- **2.2**: ADSL2plus
- **5.1**, **5.2**, **5.8**: Annex A: POTS
- **5.1**, **5.2**: Annex B: 997 A
- **5.1**, **5.2**, **5.8**: Annex B: 997 M
- **5.1**, **5.2**: Annex B: 997 B
- **5.1**, **5.2**, **5.8**: Annex B: 998 A
- **5.1**, **5.2**, **5.8**: Annex B: 998 M
- **5.1**, **5.2**, **5.8**: Annex B: 998 B
- **5.1**, **5.2**, **5.8**: Annex B: 998 0
- **5.1**, **5.2**, **5.8**: Annex C
- **5.1**, **5.2**, **5.8**: China

**US**

**DS**
ADSL2plus backwards compatibility will make VDSL2 deployment scenario much more attractive for the Carriers and will speed up the technology adoption.
Market Trends – Deployment By Region

Europe
- Triple-Play with at least 3 DTV channels + 5Mbps surfing + VoIP
- 30Mbps downstream, 3Mbps upstream
- VDSL2 compliant
- ADSL backwards compatible
- 20.5dBm transmit power
- Fits into existing ATM infrastructure
- ADSL-like long reach performance

Mainland China
- Triple-Play with at least 3 DTV channels + 5Mbps surfing + VoIP
- 30Mbps downstream, 3Mbps upstream
- VDSL2 compliant
- ADSL backwards compatible
- 20.5dBm transmit power
- Fits into existing ATM infrastructure
- ADSL-like long reach performance

USA, Canada
- Triple-Play with at least 3 HDTV channels + 5Mbps surfing + VoIP
- 30Mbps downstream, 3Mbps upstream
- VDSL2 compliant
- ADSL backwards compatible
- 17.5dBm transmit power
- ADSL-like long reach performance

Japan, Korea, Taiwan
- Upgrade of existing 70Mbps services to 100Mbps symmetrical
- 100Mbps downstream, 100Mbps upstream
- VDSL2 compliant
- ADSL backwards compatible
- 14.5/20.5dBm transmit power
- ADSL-like long reach performance
Broadband Forum’s VDSL2 Work in Progress

- **Interoperability**
  - Finalizing performance/functional requirements (WT-114 and WT-115)
  - **Interoperability test plan for VDSL2 (PD-139)**
    - Enables efficient interoperability testing
    - First plugfest planned for January 2006
    - Ongoing test events with the interoperability test labs

- **Management**
  - **Protocol Independent Object Model For Managing VDSL2 (WT-129)**
    - Based on ITU G.997.1
    - Adopting new objects from G.vdsl2
Summary

- ADSL2plus and VDSL2 offer triple play at last
  - Reach allows wider serving areas
  - Rates allow triple play and enhanced services
  - Ethernet rapidly taking over from ATM
    - Offers LAN extension type services – no signal conversion
  - Network architecture evolving faster than ever before – Broadband Forum driven
Release Plan

Provides overview and roadmap of key TRs
**BroadbandSuite Release 1.0**

**Key Capabilities**: Internet access via ADSL or SHDSL over a QoS-enabled ATM architecture. Supports VoIP transport & VoDSL

<table>
<thead>
<tr>
<th>ACCESS R1.0</th>
<th>HOME R1.0</th>
<th>CONTROL R1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR-025: Core Network Architecture for Access to Legacy Data Network over ADSL</td>
<td>TR-098: Gateway Device Version 1.1 Data Model for TR-069</td>
<td></td>
</tr>
<tr>
<td>TR-013: Interface &amp; Configurations for ADSL: Central Office</td>
<td>TR-062: Auto-Config for the Connection Between the DSL Broadband Network Termination (B-NT) and the Network using ATM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TR-061: Interfaces and System Configurations for ADSL: Customer Premises</td>
<td></td>
</tr>
</tbody>
</table>
BroadbandSuite Release 2.0 (2006-2007)

Key Capabilities:
Triple-play access via ADSL2plus over a QoS-enabled Ethernet architecture.
Full support for multicast to enable IPTV streaming.

<table>
<thead>
<tr>
<th>ACCESS R2.0</th>
<th>HOME R2.0</th>
<th>CONTROL R2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR-101 : Ethernet-centric multicast-capable architecture</td>
<td>TR-124 : Functional Requirements for Broadband Residential Gateway Devices</td>
<td>TR-130 : xDSL EMS to NMS Interface Functional Requirements</td>
</tr>
<tr>
<td></td>
<td>TR-122 : Base Requirements for Consumer-Oriented Analog Terminal Adapter Functionality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TR-068 : Base Requirements for an ADSL Modem with Routing</td>
<td></td>
</tr>
</tbody>
</table>
**BroadbandSuite Release 3.0 (late 2008)**

**Key Capabilities:** Triple-play access via GPON over a QoS-enabled Ethernet architecture. Full support for multicast to enable IPTV. Integrated remote management of Set-Top Box

<table>
<thead>
<tr>
<th>ACCESS R3.0</th>
<th>HOME R3.0</th>
<th>CONTROL R3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT-127: Dynamic Testing of DSL Transceivers with Splitters</td>
<td>TR-143: CPE Throughput Performance Test Mechanism</td>
<td>WT-159: Management Framework for xDSL Bonding</td>
</tr>
<tr>
<td></td>
<td>WT-107: Internet Gateway Device Data Model version 2 (includes bonded DSL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PD-157: TR-069 Common Managed Objects</td>
<td></td>
</tr>
</tbody>
</table>

**Work that is complete**
Thanks for taking the time to learn about our DSL related work

Check out our Release Program to learn more about related TRs