Figure 1  Reach achieved by different xDSL technologies and Spectral efficiency.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pairs</th>
<th>Symmetric</th>
<th>POTS</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSL</td>
<td>1 or 2</td>
<td>No</td>
<td>Yes</td>
<td>G.992.1, G.992.2, ANSI T1.413.2</td>
</tr>
<tr>
<td>HDSL</td>
<td>1 or 2</td>
<td>Yes</td>
<td>No</td>
<td>T1.418, 1.430, 1.431</td>
</tr>
<tr>
<td>IDSL</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>SDSL</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>SHDSL</td>
<td>1 or 2</td>
<td>Yes</td>
<td>No</td>
<td>G.991.2</td>
</tr>
</tbody>
</table>

Figure 2  Technologies comparison.
Figure 3  xDSL Reference model.

Figure 4  Structure and protocols involved in the xDSL service.
Figure 5  ANSI masks for copper qualification.
ADSL Frame

![ADSL Frame Diagram](image)

**Figure 6** ADSL frame models.

Handshake frame

![Handshake Frame Diagram](image)

**Figure 7** Handshake frame format. Messages: MS, MR, CL, CLR, ACK(1), ACK(2), NAK-EF, NAK-NR, NAK-NS, NAK-CD, REQ-MS, REQ-MR, REQ-CLR.

**Figure 8** Handshake sessions.
Figure 9  ATM Cell format according to the ATM Forum.

Figure 10  Protocol Data Unit (PDU) exchange between ATM layers.
## AAL2 format

<table>
<thead>
<tr>
<th>Channel 1</th>
<th>Channel 2</th>
<th>Channel 3</th>
<th>Channel 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CID=x</td>
<td>CID=y</td>
<td>CID=x</td>
<td>CID=x</td>
</tr>
<tr>
<td>m, n, o, p, ...</td>
<td>m, n, o, p, ...</td>
<td>m, n, o, p, ...</td>
<td>m, n, o, p, ...</td>
</tr>
</tbody>
</table>

OSF: Indicates the offset where the next CPS packet starts
UUI: Indications between end users
P: Parity Bit

```
*** ATM Cell Payload ***
```

### Figure 11
AAL2 format.

### AAL5 format

**CS-PDU:**
- User data
- PAD
- UU
- CPI
- LI
- CRC

**SAR-PDU:**
- payload
- BOM
- COM
- EOM

**PDU:**
- PAD: Complements the PDU up to forming a multiple integer of 48 bytes.
- UU: Allows for transparent data transmission between AAL5 extremes.
- CPI: Aligns the PDU in 64 bits
- LI: Data size
- CRC: G(x) = x^32 + x^26 + x^23 + x^22 + x^16 + x^12 + x^11 + x^10 + x^8 + x^7 + x^5 + x^4 + x + 1 (Calculated for the entire PDU)

### Figure 12
AAL5 format.

### Multiplexing ATM in the DSLAM

**Figure 13**
Multiplexing ATM in the DSLAM.
**Figure 14** PPP encapsulation.

**Figure 15** IP Format.

**Figure 16** Higher protocols.
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAL</td>
<td>ATM Adaption Layer</td>
</tr>
<tr>
<td>ACK</td>
<td>Acknowledge</td>
</tr>
<tr>
<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>AEX</td>
<td>A(S) extension byte; byte inserted in the transmitted ADSL frame structure</td>
</tr>
<tr>
<td>ASx</td>
<td>Any one of the simplex bearer channels (0 - 3)</td>
</tr>
<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
</tr>
<tr>
<td>ATU-C</td>
<td>ADSL Termination Unit Central</td>
</tr>
<tr>
<td>ATU-R</td>
<td>ADSL Termination Unit - Remote</td>
</tr>
<tr>
<td>BGP</td>
<td>Border Gateway Protocol</td>
</tr>
<tr>
<td>BOM</td>
<td>Begin of message</td>
</tr>
<tr>
<td>CHAP</td>
<td>Challenge Handshake Authentication Protocol</td>
</tr>
<tr>
<td>COM</td>
<td>Continuation of Message</td>
</tr>
<tr>
<td>CPI</td>
<td>Common Part Indicator</td>
</tr>
<tr>
<td>CRC</td>
<td>Cyclic Redundancy Check</td>
</tr>
<tr>
<td>DMM</td>
<td>Digital Multi-Meter</td>
</tr>
<tr>
<td>DSLAM</td>
<td>Digital Subscriber Line Access Multiplexer</td>
</tr>
<tr>
<td>EOM</td>
<td>End of Message</td>
</tr>
<tr>
<td>FCS</td>
<td>Frame Check Sequence</td>
</tr>
<tr>
<td>FEC</td>
<td>Forward Error Correction</td>
</tr>
<tr>
<td>FR</td>
<td>Frame relay</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>HDSL</td>
<td>High bit-rate Digital Subscriber Line</td>
</tr>
<tr>
<td>HEC</td>
<td>Header Error Control</td>
</tr>
<tr>
<td>HTTP</td>
<td>Hypertext Transfer Protocol</td>
</tr>
<tr>
<td>ICMP</td>
<td>Internet Control Message Protocol</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Services Digital Network</td>
</tr>
<tr>
<td>ISP</td>
<td>Internet Service Provider</td>
</tr>
<tr>
<td>L2TP</td>
<td>Layer 2 Tunneling Protocol</td>
</tr>
<tr>
<td>LCP</td>
<td>Link Control Protocol</td>
</tr>
<tr>
<td>LEX</td>
<td>L95) Extension byte; byte inserted in the transmitted frame structure</td>
</tr>
<tr>
<td>LT</td>
<td>Length Indicator</td>
</tr>
<tr>
<td>LLC</td>
<td>Logical Link Control</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>NAT</td>
<td>Network Address Translation</td>
</tr>
<tr>
<td>NSP</td>
<td>Network Service Provider</td>
</tr>
<tr>
<td>OSPF</td>
<td>Open Shortest Path First</td>
</tr>
<tr>
<td>PAD</td>
<td>Padding</td>
</tr>
<tr>
<td>PAT</td>
<td>Port Address Translation</td>
</tr>
<tr>
<td>PAP</td>
<td>Password Authentication Protocol</td>
</tr>
<tr>
<td>PAP</td>
<td>Permanent Virtual Circuit</td>
</tr>
<tr>
<td>PDU</td>
<td>Protocol Data Unit</td>
</tr>
<tr>
<td>POTS</td>
<td>Plain Old Telephone Service</td>
</tr>
<tr>
<td>PPP</td>
<td>Point to Point Protocol</td>
</tr>
<tr>
<td>PT</td>
<td>Payload Type</td>
</tr>
<tr>
<td>PVC</td>
<td>Permanent Virtual Circuit</td>
</tr>
<tr>
<td>RADSL</td>
<td>Rate Adaptive Digital Subscriber Line</td>
</tr>
<tr>
<td>SAP</td>
<td>Service Access Point</td>
</tr>
<tr>
<td>SAR</td>
<td>Segmentation and Reassembly</td>
</tr>
<tr>
<td>SDH</td>
<td>Synchronous Digital Hierarchy</td>
</tr>
<tr>
<td>SDL</td>
<td>Symmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>SHDSL</td>
<td>Symmetrical High Bit Digital subscriber line</td>
</tr>
<tr>
<td>SMTP</td>
<td>Simple Mail Transfer Protocol</td>
</tr>
<tr>
<td>SNTP</td>
<td>Simple Network Management Protocol</td>
</tr>
<tr>
<td>STF</td>
<td>Start Field</td>
</tr>
<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
</tr>
<tr>
<td>TDR</td>
<td>Time Domain Reflectometer</td>
</tr>
<tr>
<td>UDP</td>
<td>Universal Datagram Protocol</td>
</tr>
<tr>
<td>UU</td>
<td>User-to-User indication</td>
</tr>
<tr>
<td>VCI</td>
<td>Virtual Channel Identifier</td>
</tr>
<tr>
<td>VPI</td>
<td>Virtual Path Identifier</td>
</tr>
</tbody>
</table>