Optical Extension of XDSL: Options for fibre penetration into the Access Network

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Growth of broadband deployments
What is fuelling this growth?
The current access network
Copper DSL deployments
Fibre/copper DSL deployments
Growth of broadband deployments

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- Copper DSL deployments
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Moore’s Law for *Commercially available* broadband services

- 2x every 18 months

![Graph showing the evolution of broadband access technologies from 1985 to 2010. The graph plots Mbps (Mbit/s) on the y-axis and years on the x-axis. Key technologies include ISDN, V.34, V.90, ADSL/Cable, FTTH, and VDSL. The graph indicates a doubling every 18 months from 1985 to 2005.](image)
150M broadband subscribers worldwide

- 100M DSL subscribers Q1 2005 (62% share)
  - expected to exceed 140M by end 2005
- DSL subscriptions grew 58% in 2004
- Remaining 38% comprises mainly cable, although growth now low due to DSL availability
- Some FTTH deployments in last year or two, most notably in Japan (5m by 2006) and Korea
Current Deployment Trends – by Country

Source: Point Topic 2004
Current Deployment Trends – by Country

Source: Point Topic 2004
Broadband penetration – Shows geographic attitude towards broadband

Source: Point Topic 2004
Growth of broadband deployments

What is fuelling this growth?

- The current access network
- Copper DSL deployments
- Fibre/copper DSL deployments
Current drivers – Internet traffic

- Peer to peer communication continues to dominate current network traffic
  - Symmetric load
  - Now accounts for 50-70% of all Internet traffic
- Online Internet gaming accounts for >10% of Internet traffic
  - Gaming will be >30% of US Internet traffic by 2008 with predicted revenues of >$4Bn
  - 90% of Internet users in Korea use it for gaming
- File sharing shift from MP3s (3-5 MB) to DVDs (700 MB)
### Future bandwidth requirements - summary

<table>
<thead>
<tr>
<th>Application</th>
<th>Downstream requirement</th>
<th>Upstream requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HDTV</strong></td>
<td>60 Mbit/s</td>
<td>&lt;1 Mbit/s</td>
</tr>
<tr>
<td>(3 per home at 20 Mbit/s each)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard TV = 4.5Mbit/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Online gaming</strong></td>
<td>2-20 Mbit/s</td>
<td>2-20 Mbit/s</td>
</tr>
<tr>
<td><strong>VoIP Telephone</strong></td>
<td>0.3 Mbit/s</td>
<td>0.3 Mbit/s</td>
</tr>
<tr>
<td>(3 per home at 100kbit/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data/ Email etc</strong></td>
<td>10 Mbit/s</td>
<td>10 Mbit/s</td>
</tr>
<tr>
<td><strong>DVD download for rental</strong></td>
<td>14 Mbit/s</td>
<td>&lt;1 Mbit/s</td>
</tr>
<tr>
<td>Assume download must take &lt;10 mins i.e. the time to get one from a rental store</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>~100 Mbit/s</td>
<td>~30 Mbit/s</td>
</tr>
</tbody>
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100 Mbps no longer looks like a luxury
Growth of broadband deployments

What is fuelling this growth?

The current access network

Copper DSL deployments

Fibre/copper DSL deployments
UK copper access network

- Built for telephony up to 80 years ago
- 29 m copper pairs
- 5600 exchange buildings
- 1.5 m DP poles

- CO
  - Up to 10,000 pairs
  - 1.5 km – E Side

- PCP
  - 250 - 300 way
  - 0.6 km – D Side

- DP
  - 16-way (24 = 99%)

- CPs
Alternative Access Technologies

- In addition to Copper
  - **Cable** – Widely deployed, particularly in US and Canada. Primarily for TV broadcast services.
  - **Fibre** – Very low penetration due to present cost issues, some residential FTTH in EU but mainly commercial office/campus networks.
  - **Satellite** – Seen as last resort option for remote CPs, very expensive.
  - **3G cellular wireless** – Some services becoming available.
  - **Wireless** – WiMax etc. – Promising but still early stages.
Narrowband - Dialup

- Data Communications to the home
- Dialup – dominant until late 1990’s
  - Transmitting directly over the ~3kHz voice channel
  - Limited by 64 kbps digitisation at exchange
  - Mid 1990s V.34 standard QAM based – Shannon limited to ~33 kbps over available bandwidth
  - Mid/late 1990s V.90 standard PCM based – relied on the digital PSTN exchange, could theoretically therefore reach the 64 kbps (although standard limited to 56 kbps)
- Data OR Voice
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DSL LAN wiring configuration

- Potential of DSL for home networking or SME LAN interface
DSL - Impairments

- Noise
  - Switches, lighting, power lines, AM broadcasting, Ham radio

- Crosstalk
  - NEXT – reflected back to adjacent receiver
  - FEXT – Cross coupling between adjacent wires in binder, attenuated by the line
  - NEXT dominates FEXT where it occurs although reduced for example by non-overlapping DS/US frequency bands

- Bridged taps
  - Tap cable not in the direct CPE-CO path, can result in echoes and attenuation glitches

- Attenuation…
ADSL Impairments - Attenuation

- Network was built for voice traffic
- Primary limitation to transmission distance
- Leads to reduced SNR at far end
- 1km (3.3kft) of 24AWG Cat-3 cable
Survey average loop length

% Cumulative

Distance (km)

Source: IEEE
Discrete Multi-tone Modulation

One of the main modulation formats employed in DSL


Although some early adopter VDSL based on CAP/QAM format

Attempts to make best use of poor quality transmission channel

Transmitting multiple tones each carrying narrowband QAM signal

Handshaking between modems sets out water-filling or bit-loading condition for each of the tones depending on link quality at tone frequency
ADSL - DMT modulation

- Voice band (baseband) for first 4kHz
- POTS splitter to separate voice and data signals
- ADSL = 256 carriers, spaced ~4 kHz apart within 1.1 MHz analogue bandwidth
- 26 - 138 kHz for US, 138 kHz - 1.1 MHz for DS
- Each carrier supports QAM signal at a level determined by water-filling
- Tones bit loading may be reduced or increased in line with SNR at that frequency
- Total data transmission is the sum of contributions from all tones
Example of link loss and bit-loading characteristics for typical clean 9 kft (2.7 km) link

In this example, the ADSL modems established a link with data rate of 7008 kbps DS
Example of link loss and bit-loading characteristics for 9 kft (2.7 km)
Here, the link attenuation is slightly degraded by the presence of a bridged tap after 300 ft
Here a data rate of 5888 kbps DS was achieved
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VDSL

- Very high data rate DSL
- The next evolutionary step from ADSL
- VDSL supports up to 52 Mbps DS
- Reach limited to typically <1 km
- VDSL2/VDSL2+ now achieving 150 Mbps over 300 m
- Requires a change of network architecture to accommodate its’ shorter reach capabilities
Based on lab measurements, so are optimistic.
Fibre extend reach due to low attenuation, crosstalk impairments
Street node contains DSLAM, higher layer transmission protocol between ONU and OLT
This configuration called the RDSLAM (remote)
ONU options

- RAM – Remote Access Multiplexer
- Low profile version of the RDSLAM designed to fit into cabinet, avoiding the need for additional cabinet
- Smaller size and lower cost – can be squeezed into existing cabinet space
- May be externally powered
- Up to 48 subscribers per unit
ONU options

- SAI-based DSLAM – (service area interface)
- Deep fibre penetration (FTTcurb) required
- Due to remote nature must be rigorously industrially hardened
- Line powered – potentially from the CO
- Can be placed virtually anywhere and may be used to extend to the fringes of a DSL network
- Picture shows 24-port ADSL DSLAM
ONU options

- Fibre-optic DSL extender (virtual DSLAM as DSLAM remains in CO)
- Extends existing CO DSLAM signal to remote cross-connect cabinets
- Multiplexes DSL signal over GigE interface (for example)
- Facilitates delivery of DSL to remote outreaches
- May reach 25 km from the CO (more typical of US networks)
- Research at UoE within Muse looking at carrying analogue DSL signals between CO and CPE
- Retains DSLAMs at the CO
- Low cost, low power interfacing hardware at Curb, possibly power fed from
- Optical hardware consists of single transmitter for the (potentially) 25 CPEs
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Sub carrier multiplexing

Baseband VDSL signal

Optical carrier direct modulation spectrum

$f_1$, $f_2$, $f_3$, $f_4$, $f_5$, 300MHz, $f_N$, 1GHz

12MHz
Summary

- Residential broadband requirements moving towards 100Mbps
- Large existing infrastructure dominated by copper links
- DSL best current technology for using existing network capabilities
- DSL remains a low cost deployment option due to low CPE costs
- Reach limitations will demand rethink of this infrastructure if bandwidth provision is to increase
- Finally, briefly mentioned some fibre penetration scenarios
Thank you for your attention.