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Future Digital Subscriber Line (DSL) Technology

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Contents

1 Foreword

This Briefing Note has been prepared as a follow-up to the 'Innovation in Communications – Planning for the Future' symposium held by the ODTR[1] in June 2002. Both the symposium and the Briefing Note series come under our Forward-looking Programme, and primarily deal with technology developments in the telecommunications sector.

This Briefing Note is about developments in digital subscriber line (DSL) technology which is one of the key technologies for delivering broadband services in Ireland. Broadband access is, and will increasingly become, an essential element helping to drive the development of the ICT sector (see Consultation on 'Future Delivery of Broadband in Ireland', September 2002)[2]. The increased bandwidth available through technologies such as DSL will help enable the provision of an array of new broadband business and residential applications such as those described in a previous Briefing Note 'Potential Applications for Next Generation Networks'[3]. Some of these applications will individually require high data rates (e.g. high quality video) whereas the aggregate effect of multiple lower speed applications is also likely to require higher capacities on telecommunications networks.

DSL is now being deployed in Ireland and by October 2002 there were 1900 DSL subscribers[4]. There are currently approximately 80 eircom DSL enabled exchanges and 40 'unbundled' exchanges. Whilst the headline number of customer deployments using new DSL technologies is low, the exchanges at which the technology is available cover at least one third of the total telephone lines in Ireland. Although mainly ADSL has been deployed to date, other versions of DSL are available or are being developed, and these are beginning to emerge in Ireland and abroad.[5]

This Briefing Note seeks to explain how DSL works and the range of DSL equipment there is available and is coming on stream. It does not address the financial aspects of its deployment for operators or the specifics of take up by users. However, it is recognised by ComReg that the various costs and charges that underlie DSL introduction are critical factors in how quickly DSL deployment takes place in Ireland.

DSL technology is evolving fast and one of the most promising developments for Ireland is new mini DSLAMs[6], or 'pizza boxes' which are smaller and cheaper and should extend the range of availability of DSL without adding to the cost. In outlining these and other developments such as self-installable DSL, we hope to help stimulate wider choice of communication technologies and services in Ireland.

If you are interested in knowing more about the technology or installing it in your home or business, you may find the list of contacts at Annex 9.9 useful.

Etain Doyle,

Chairperson,
Commission for Communications Regulation

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[1] Office of the Director of Telecommunications Regulation – The ODTR was replaced by ComReg in December 2002.

[2] ODTR Document Number 02/79 – www.comreg.ie/docs/odtr0279.pdf

[3] ODTR Document Number 02/45 – www.comreg.ie/docs/odtr0245.doc

[4] ComReg Quarterly Market Review - www.comreg.ie/docs/ComReg02106b.doc

[5] It should be noted however that not all the technologies described in this Briefing Note can co-exist, as there would be interference between different standards. Therefore, not all of these solutions can be deployed in Ireland (See Section 4.4).

[6] DSL Access Multiplexer – See Section 4.

2 Comments on this Briefing Note

We welcome any comments or views on this Briefing Note and these should be sent to:

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to arrive on or before 5.30pm on Friday 21st February, 2003.

In submitting comments, respondents are requested to reference the relevant section of this document. Responses will be available for inspection by the public on request. Where elements of any response are deemed confidential, these should be clearly identified and placed in a separate annex to the main document.

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3 Introduction

This Briefing Note is intended to raise awareness of technology developments in the area of Digital Subscriber Line (DSL). It is targeted primarily at non-technical readers with some background technical awareness of the telecommunications industry.

3.1 What is DSL?

DSL is a method of increasing the bandwidth or information-carrying capacity of existing copper telephone lines in the 'last mile' or local loop segment between customers and local exchanges, enabling the delivery of a type of always-on, broadband access. The most commonly used version of DSL can typically deliver data rates between 5 and 50 times greater than 56kbit/s dial-up modems by placing digital equipment on each end of the line. Providing customers with these DSL services requires operators to install new DSL equipment in their local exchanges. End users also need DSL equipment, (e.g. modems and in some cases splitters – see Section 4), installed in their premises to avail of DSL.

Incumbent operators are required to provide access to copper lines for new entrants who may themselves enhance the lines with DSL. The process of providing access is known as local loop unbundling (LLU). DSL services may be provided by an incumbent operator as a 'bitstream' service for example. Where an incumbent provides bitstream access itself, it must also provide wholesale bitstream access to others. ComReg is engaged in ongoing work with telecommunications operators in relation to these issues. LLU issues are generally outside the scope of this Briefing Note and readers wishing to obtain further information on this topic should consult the ComReg website[7].

3.2 What can DSL be used for?

A range of services including high speed Internet and voice can currently be delivered using this technology, and with further developments the delivery of higher bandwidth services such as video will become more practicable shortly. Many residential users and SMEs start by upgrading to DSL services running at 256kbit/s or 512kbit/s and then graduate to higher speeds. With potential data rates in excess of 2Mbit/s, DSL can in principle be used by SMEs to meet extensive broadband communications needs and also by residential users for communications and entertainment such as video services.

All ADSL services are always on, so users can regard the Internet as an open book, with e-mails and other information immediately accessible. Currently, smaller companies typically use the Internet for e-mail and research, and these applications are enhanced with a good DSL connection, as is the opportunity to develop Internet presence and business interaction both at home and abroad.

Documents can be exchanged very much more quickly using DSL than with a normal dial-up modem. For example, 60 pages of typewritten material which might take one minute over a 56kbit/s modem, would take only 14 seconds at 256kbit/s and 7 seconds at 512kbit/s (i.e. typical ADSL data rates). Graphics can be downloaded more quickly also. For example a full colour photo or technical drawing can be downloaded in 10 seconds using ADSL as compared with one and a half minutes using a dial-up modem. In general, speed is important for the development of e-commerce

[7] www.comreg.ie/docs.asp?Type=Category&Category=Local+Loop+Unbundling&Image=images/unbundling.gif

transactions as users can become discouraged by the length of time it may take to download a series of pages necessary to complete transactions.

For more heavy duty uses, for example, a data file of 7 GBytes, which is about the size of a typical feature-length film, would take around 12 days to download using a 56 kbit/s dial-up modem. With ADSL operating at say 2 Mbit/s and future DSL at say 52 Mbit/s, the same data file could be downloaded in 8 hours and 19 minutes respectively.

An important feature of DSL-based services is the 'always-on' access capability. The customer typically pays a flat rate fee and can then, for example, be permanently connected to e-mail and electronic business services and use them interactively. In this way the customer is not charged for the duration of connection, but may in some circumstances be charged for the amount of data sent over the link.

Advanced DSL systems will in the future be able to deliver high capacity applications such as three dimensional video for education or design applications, high speed grid-computing, multi-party video conferencing, and other applications as described in the 'Potential Applications for Next Generation Networks' Briefing Note[8]. Narrowband, or low data rate applications, despite individually requiring lower capacities, could also lead to significant demand for high capacity DSL access links through the aggregate effect of multiple applications running at the same time.

[8] www.comreg.ie/docs/odtr0245.doc

4 How DSL works

4.1 Digital Signals on the Copper Local Loop

A voice signal utilises only a small portion of a copper line's information carrying capacity[9]. When using a dial-up analogue modem to connect to the Internet, the digital information is adapted such that it uses no more resources on a copper telephone line than a voice call. This allows the data to be carried through the rest of the telephone network (typically yielding up to 56 kbit/s). Using DSL technology much greater data rates are achievable on a standard copper local loop by utilising more of the cable's information carrying capacity[10]. By attaching DSL equipment to each end of a local loop, high speed digital signals can be transmitted over the higher frequencies where there is unused capacity. Prior to the emergence of DSL products for SMEs and residential customers, leased lines were provided using "high bit-rate DSL" technology (HDSL – see next section). ISDN is another, older, form of digital transmission used on standard copper local loop lines.

For a copper loop to carry DSL, a DSL Access Multiplexer (DSLAM) is needed at the operator's local exchange and a DSL modem, router[11] or switch is required at the customer's premises (see Annex 9.2). With Asymmetric DSL (ADSL) the analogue voice portion of a signal on a local loop is separated from the digital portion using a device called a 'splitter', which then allows the existing telephone services to be carried as well as the higher frequency DSL services.

4.2 Different types of DSL

Different types of DSL have emerged and are under development to suit various usage profiles and networks. Some can deliver higher data rates while others can operate over longer distances. Although some of these DSL systems can be substantially different in terms of their physical characteristics they all operate with similar basic components (i.e. copper loop, DSLAMs, DSL modems) using the same basic principles.

Broadly speaking, the various types of DSL can be divided into two main categories: symmetrical and asymmetrical. Asymmetrical DSL systems such as ADSL and Very high speed DSL (VDSL) are designed to provide greater data rates in the downstream direction (i.e. to the customer) than in the upstream direction (i.e. to the operator). This type of arrangement is suitable for Internet access, particularly in situations where users are downloading more information than they send back, and for broadcasting applications such as interactive TV.

Symmetrical DSL systems such as Single-pair High-speed DSL (SHDSL) and ISDN DSL (IDSL) are suited to users who require the same amount of capacity in both the upstream and downstream directions. Currently these users are typically business users, but in the future residential users might be expected to use applications requiring symmetrical access (e.g. peer-to-peer sharing of music and video files). See Table 1 for the main characteristics of various types of DSL, and Annex 9.4 for more detailed descriptions.

[9] using 3kHz of spectrum (between 300Hz and 3.4kHz)

[10] DSL uses higher frequencies than a voice signal. This is analogous to replacing single deck buses with double deck buses to transport more people on the same size roads (although VDSL – see Annex 9.1 - would be the equivalent of a 4000 deck bus compared to the PSTN).

[11] A device used to deliver traffic in an Internet Protocol (IP) network.

Type	Description	Data Rate (bit/s) – See Section 4.3		Range[12]	Typical Uses	Typical users
		Up[13]	Down			
V.22[14] to V.90	Analogue Modems	12k – 56k	12k – 56k	Length of PSTN Local Loop	Dial-up, basic Internet	Residential
IDSL	ISDN DSL	160k	160k	5.5km	Always-on, faster Internet	SOHO[15]
HDSL	High Bit Rate DSL	2.3M	2.3M	3km	Two way high speed data, leased lines	SOHO/SME
SDSL	Symmetric DSL	2M	2M	300m - 1.4km	Two way high speed data	SOHO/SME
SHDSL	Single Pair High Speed DSL	128k–2.3M	128k–2.3M	1.8 – 6.5km	Two way high speed data	SOHO/SME
ADSL	Asymmetric Digital Subscriber Line	16k – 640k	1.5M – 8M	4.2km	Most common type of DSL, high speed Internet uses	Residential/SOHO
ADSL Lite[16]	Splitter-less ADSL	96k – 256k	512k – 1.5M	2.8-4.2km	Self-installation, high speed Internet, not used for voice	Residential/SOHO
RADSL	Rate Adaptive DSL	128k – 1M	1.5M – 9M	5.5km	DSL used on lower quality/ longer lines	Residential/SOHO
VDSL	Very High Data Rate DSL	1.6M–6.6M/26M	13M – 52M	300m – 1.5km	Multiple video streams + high speed Internet	SME/High end residential

Table 1: Comparison of the main DSL technologies.

4.3 Local Loop Length, Data Rates and Ranges

For a given DSL technology the achievable data rate is dependent on a number of factors including the length of the line and its diameter and condition of the cables used. The typical range for ADSL, provided that the local loops are in good condition is about 4 km. However, low cost narrower gauge[17] cables, typically found in some older local loops, are less capable of carrying high speed data than broader gauge cables. Other disturbances in the local loop[18] can impair the ability of a line further, and therefore operators must assess lines for compatibility on an individual basis. These factors often result in commercial service offerings with shorter ranges and lower capacities than those listed in Table 1. Service providers typically offer ADSL at downstream rates of between 256k and 2Mbit/s, and upstream rates of between 128 and 256kbit/s.

[12] It is important to note that the DSL ranges listed represent the total line length, and not a radial distance from the local exchange since local loop lines typically follow indirect paths along roadsides to subscribers.
[13] 'Up' means the direction from the customer to the operator.

[14] Analogue dial-up modems are not a DSL technology and are included for comparison only.

[15] Small Office Home Office

[16] Also know as DSL-Lite, G.Lite, G.992.2

[17] Gauge is the term used for the physical thickness or diameter of a cable.

[18] E.g. un-terminated sections of cable connected to the local loop, known as 'bridge taps', can reduce the quality of a line.

In Ireland, as in other countries, some of the PSTN lines are longer than 4km, and therefore might be unsuitable at present for DSL. However, there are a number of approaches that may alleviate this. It would appear that one relatively inexpensive approach is for operators to install miniature DSLAMs[19], either alongside or integrated with remote terminals such as concentrators and digital loop carriers (DLC) in the PSTN (e.g. in street cabinets)[20]. This approach would bring an operator's DSL access points (i.e. DSLAMs) closer to end users[21], (see also Section 6.3). Over time it is likely that incremental technology developments will continue to extend the reach of DSL technologies. When combined with deployment of fibre to the cabinet access network, this should enable DSL to be brought to subscribers who are located further than 4km from their local exchanges.

4.4 Spectrum resources and installation

As mentioned above, DSL systems use more spectrum on a copper cable than traditional voice or other PSTN services (e.g. dial-up Internet). This can increase the chances for interference between different DSL users and PSTN users when their local loop cables are grouped together by the operator in the same cable bundle or binder[22]. Because of this, frequency planning has to take place when provisioning DSL services to avoid such interference, (see also Section 7.4). [23]

An important development in DSL systems are modems that can be installed by the user without the need for manual configuration by network engineers. Self-installation should lead to lower setup costs per customer. Self-installation is typically done using kits that include low cost filters (splitters), a DSL modem and configuration software that the users can install themselves[24]. These solutions are not currently available in Ireland.

4.5 Standards bodies

National, regional and international standards and industry bodies have been working on DSL standardisation with a view to increasing interoperability and compatibility of DSL technologies and products. Standardisation difficulties have in some cases delayed the introduction of DSL technologies (e.g. VDSL), because manufacturers and operators often wait for standards to be agreed before implementing new technologies. The main standards bodies are ITU, ETSI, ANSI, and IEEE. A list of some important standards can be found in Annex 9.8.

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[19] Such devices are often called 'pizza box' solutions due to their small size.

[20] E.g. 'Stinger Micro-Remote Terminal (MRT)' from Lucent Technologies.

[21] Sometimes for service compatibility reasons not all of these approaches are allowable – see Section 7.4 which deals with the Frequency Management Plan.

[22] A bundle/binder is a number of twisted pair copper lines grouped together in a multi-pair cable – e.g. from the cabinet to the exchange. A typical cable might carry 10 pairs of cable – i.e. serving ten customers.

[23] The use of higher frequencies by DSL systems, (e.g. VDSL, which can operate above 12MHz), could leave them vulnerable to interference from HF radio systems if they are not properly shielded resulting in reduced data rates and range. Often older cables are not sufficiently shielded for such high frequency systems, due to factors such as wear and tear, older materials and old installation methods. Furthermore DSL systems must be designed and installed such that they avoid causing interference to radio based systems through spurious emissions.

[24] Splitter-less systems such as ADSL Lite (G.Lite) can also be installed by the user (See Annex 9.4).

5 Comparison with other access technologies

DSL has an important advantage over most other broadband access technologies in that it can utilise much of the existing installed base of copper lines in the local loop, thus eliminating the need to dig and lay new cables or to erect masts. Other access technologies do however have certain merits that can make them viable alternatives in many cases, and indeed sometimes they can provide broadband access where DSL cannot. The main alternative access technologies are:

- Cable (Hybrid Fibre/Coax)
- Optical access
- Fixed wireless access (including wireless LANs)
- Satellite

Each of these technologies may be more or less suited to different situations depending on factors such as geographic locations, demographics, roll-out strategies and user profiles.

	Advantages	**Disadvantages**
DSL	Uses existing copper infrastructure Can be rolled out incrementally Well established and understood technology Dedicated local loop line per user	Availability depends on length and condition of line Up-grade costs e.g. exchanges, installation of DSLAMs, can be high
Cable (HFC)	Operators have extensive experience with video Can use some existing infrastructure	Expensive to upgrade: Shared medium with contended bandwidths: Up-link capacity can be limited
Satellite	Nationwide availability; good for broadcast Backhaul infrastructure not needed[25] Low installation and set-up time (once satellite is operational)	Latency/delay (poor for interactivity, e.g. not suitable for voice/video conference) Limited dedicated capacity per user (shared medium) Cost and time taken to launch a new satellite can be prohibitive[26]
Fixed Wireless Access	Rapid roll-out Avoids digging costs	Some systems need line of sight which may require high antenna towers: equipment may be expensive.
Optical Access	High capacity Future proof long term solution	Costs can be high where new cable must be installed[27] Still developing as an access technology

Table 2 – summary comparison of main access technologies

[25] Except for link between service provider and satellite gateway earth station. The satellite itself is typically owned by an international satellite company.

[26] Typically only undertaken by companies targeting large markets that may span multiple different countries.

[27] Optical wireless (or Free Space Optics) utilises optical technology to deliver high speed communications (up to several Gbit/s) without the need to install cables – see ODTR briefing notes on Optical Wireless (www.comreg.ie/docs/odtr0159.doc) and Optical Access (www.comreg.ie/docs/odtr0229.doc).

6 Technology Developments

6.1 DSL variants

Existing telecommunications network operators are likely to continue to use DSL technologies to maximise their investment in copper infrastructure for some years to come. As users demand higher capacity broadband access, operators will need more advanced versions if they are to use DSL to meet user requirements. Furthermore, high capacity, always-on access can enable operators to create new revenue generating opportunities through advanced new services.

6.1.1 ADSL, ADSL+ and ADSL2+

New DSL standards that can enable even higher capacity communications are emerging while others are still under development. An updated version of ADSL called 'ADSL2' is being defined by the ITU[28]. As well as slight capacity and range increases compared to ADSL[29], ADSL2 will be more flexible and interoperable, and will have increased functionality. An optional addition to the standard, still under development, allows for increased data rates in the downstream direction, possibly in excess of 16 Mbit/s, through the use of twice as much spectrum as ADSL (i.e. 2.2MHz). This type of ADSL, which will typically only be useful on local loops less than 2.7km in length, is also known as ADSL2+, ADSL+[30] and Fast ADSL[31]. ADSL2 and ADSL2+ could emerge as up-grades to ADSL, co-existing in the same DSLAMs with replacement line cards thereby reducing up-grade costs. Once standards have been adopted it is likely that more products will become available. This should result in lower costs, (and create a potential competitor to SHDSL systems – see below).

6.1.2 Single-pair High-speed DSL

To address the SME business market and some potential residential applications (e.g. peer to peer communications) a symmetrical form of DSL, delivering up to 2Mbit/s[32] in both directions has been developed. It is known as Single-pair High-speed DSL (SHDSL[33]) and operates over a single copper pair at ranges up to 6.5km[34]. The key difference between SHDSL and ADSL is that SHDSL achieves higher upstream speeds, as it uses the lower frequency capabilities of the copper as well as the higher frequencies. This is possible because SHDSL does not support existing standard telephony service on the line. Typical applications could be voice over IP, data, LAN interconnection, video conferencing, interactive multi-media, remote learning, and advanced data-base applications. SHDSL is a standardised (ITU G.991.2) replacement for SDSL with approximately 30% greater reach. The ANSI standard HDSL2 is a

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[28] These ITU standards are currently in the pre-published stage.

[29] Generally speaking ADSL2 will produce a data rate increase of 50kbit/s over standard ADSL for a given loop length, or a range increase of about 150 metres for a given data rate. – Source: Aware Inc.

[30] The term ADSL+ is also being used as a product name for standard ADSL by some companies.

[31] Standards have been developed for ADSL2 systems with and without splitters (ITU G.992.3 & G.992.4 respectively) – see Section 4.4

[32] Fractional data rates are available at multiples of 128kbit/s to suit user needs and transmission environment (e.g. line length, noise on line). Modems that operate on 2 and 4 pairs of cable could yield data rates between 4.6 and 9.2Mbit/s, making them suitable for business users with higher capacity needs.

[33] SHDSL is also sometimes known as Synchronous HDSL.

[34] 2 pair systems can be used for extended reach applications

competing technology. SHDSL is suitable for installation alongside other types of DSL[35].

SHDSL is currently being implemented by Deutsche Telekom in ten German cities and BT has had SHDSL under trial since October 2002 (BT DataStream Symmetric, BT IPStream Symmetric). Other operators including Telekom Italia are also deploying the technology. SHDSL is likely to emerge in Ireland in the near future.

6.1.3 Very high speed DSL

Very high-speed DSL (VDSL) is a developing type of DSL that is expected to provide asymmetrical connections with downstream data rates of between 13 and 52Mbit/s over a single copper pair at ranges up to 1.5 km. Upstream data rates of between 1.6 and 26Mbit/s are planned (26Mbit/s in symmetrical mode only).

Range	300m	1km (symmetrical)	1km	1.5km
Data Rate Up	6.6M	26M	3.2M	1.6M
Data Rate Down	52M	26M	26M	13M

Table 3: Potential VDSL range and data rates

The high downstream data rates that VDSL is expected to deliver will support applications such as video on demand. This will enable users to receive for example more than one video stream while also using the line for other services such as voice and Internet. This combination of voice, video and data over VDSL is known as full service VDSL (FS-VDSL)[36]. The main demand for such data rates at present would be among business users wishing to support applications such as multiple Internet connections or video conferencing. However, residential users could potentially require such data rates for applications such as one-way or two-way high quality video[37] (e.g. peer-to-peer video file transfers, 'videoconferencing' between family members and friends).

VDSL's range limitation and high data rates will mean that fibre optic networks would need to be rolled out closer to customers than they are at present[38]. This would require significant investment from network operators to bring fibre and electrical power to kerb-side cabinets. However, it is to be expected that VDSL equipment prices will fall over time. In some cases VDSL could be installed in existing DSLAMs, but would only be able to reach a limited number of customers.

Qwest Communications, in the USA, has deployed VDSL to 50,000 subscribers, with 400,000 homes passed. Roll-out has mostly been in new housing developments with customers paying up to $75/month for digital TV and Internet access up to 3Mbit/s. VDSL has been trialled by eircom to 100 users in Ennis, Co. Clare, initially as part of the Information Age Town initiative[39]. Other trials are being conducted by operators in other countries e.g. Bell Canada, Telecom Italia and Telenor (Norway). Bell Canada already has a 'triple play' (i.e. voice, video and data) service and plans to extend this service to apartment buildings using VDSL.

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[35] The available data rate of SDHSL may vary with line length in accordance with frequency management plans.

[36] www.fs-vdsl.net/

[37] BT Exact has created a Broadband Home/Broadband Office (BHBO) demonstration using VDSL technology that can simultaneously delivery high quality video signals and high speed Internet access - www.btexact.com/ideas/features?doc=42475

[38] It is possible that other technologies such as Optical Wireless could be used to make high speed connections between cabinets and the backhaul network.

[39] www.ennis.ie/cgi-bin/eiat.cgi?page=news_archive_2002-02.htm#Free_Internet_Access_for_Ennis_Homes2002-02-22

6.2 Need for fibre back-haul

As described above, extensive fibre roll-outs will be needed to handle the extra capacity required by systems such as VDSL. The aggregate effect of higher capacities from other types of DSL such as SHDSL at 2 Mbit/s would also, in many cases, require fibre to be rolled out further towards customers. This would prevent the situation where too many users are competing for high capacity access on a particular DSLAM. However, it may also be the case that once fibre is brought sufficiently close to customers premises, short range wireless technology might in some cases be used to make the final access connection, as an alternative to DSL[40].

6.3 Miniature DSLAMs

Miniature DSLAM technology intended to enable relatively inexpensive, small scale deployments of DSL has been developed fairly recently, (see also section 4.3) [41]. These devices are designed to be suitable for use in small exchanges and are also intended for deployment in a number of other situations, including in street cabinets and for wall mounting. Such systems reduce the amount of equipment and cabling at a particular site by consolidating multiple DSL elements into a single unit. They typically are intended to support from about half a dozen to around a hundred subscribers, and are designed to support both ADSL and SHDSL line cards.

6.4 Ethernet over the Copper Local Loop

A large proportion of telecommunications traffic both starts and ends on computer networks in offices and universities. These local area networks (LANs) are typically operated using an IEEE standard known as Ethernet. In November 2000 the IEEE created an 'Ethernet in the First Mile'[42] study group (IEEE 802.3ah[43]) which is developing a specification for using the copper local loop to carry Ethernet traffic. Such a standard could help extend Ethernet from the LAN to the metro area network (MAN). Operators may also be able to avail of Ethernet's scalability while deploying this type of DSL service. VDSL is one technology that could be used for Ethernet (EoVDSL). Although priority solutions for Ethernet over DSL are currently available (e.g. EtherLoop from Paradyne[44]) it is too early to determine how successful Ethernet technology will be in the local loop.

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[40] Other techniques such as those developed by RAD Data Communications, Israel, could use fibre to extend the reach of DSL by carrying the DSL signal over fibre between the DSLAM and a cabinet nearer the customer, before running it over copper for the final link.

[41] For example, the Fujitsu FDX Mini

[42] Ethernet in the First Mile Alliance - www.efma.org

[43] IEEE 802.4ah is now a task force. Baseline specifications were agreed in July 2002, and a first draft specification is expected shortly.
http://grouper.ieee.org/groups/802/3/efm/public/index.html

[44] www.paradyne.com/technology/etherloop.html

7 Market Development

The deployment of DSL is dependent on various factors including subscriber demand, service pricing, equipment costs, and the state and layout of the PSTN. Competitive issues such as the availability of alternative providers of access are also key factors in the market's development.

7.1 Potential Market

From a customer's perspective the telephone line is a familiar means of receiving telecommunications services due to the high penetration of dial-up Internet access and ISDN. The residential DSL, small office/home office (SOHO) and SME markets seem likely to focus initially on high speed Internet access. Users who currently subscribe to second lines for Internet access are potential DSL subscribers, as this would enable them to avail of both voice and Internet on a single line. As a result of DSL deployment, new video applications could also potentially become viable. The remaining business DSL market is more likely to develop from low-end leased line replacement needs which could have a significant impact on this segment of the market. DSL is also likely to be taken up by current ISDN customers seeking greater data rates and always-on access. Deutsche Telecom, among others, has been marketing ADSL to its existing ISDN customers as an additional incremental service. Furthermore, as penetration rates of high speed access increase, new high capacity applications and content are likely to develop.

An important characteristic of DSL technology is its always-on access capability. For some users, always-on connectivity is a more important aspect of broadband communications than high capacity. With always-on access, users need not dial-up their operator to make a connection every time they wish to check their e-mails for example[45]. Always on access generally requires operators to adopt new approaches to charging for their services. These typically involve monthly 'flat-rate' subscriptions, sometimes with additional charges related to the amount of data communicated[46].

Advanced trials of broadband access technologies, including various types of DSL, in the Information Age Town in Ennis[47] and the Digital Hub in Dublin[48], could demonstrate the value of new applications and high speed Internet access to operators and potential users elsewhere. Furthermore, the special environments provided by such test-bed projects could allow service providers to experiment with alternative business models.

From an operator's perspective, the additional capacity provided by DSL systems could enable it to implement innovative new services and applications to generate new sources of revenue. European revenues in the residential market for ADSL were predicted to be worth over €8 billion by 2006[49], compared to €2.4 billion for cable modems. These revenues reflect a predicted increase in subscriber numbers over the period forecast, and the possibility that average revenue per user (ARPU) levels may drop as a result of falling prices. Operators could however expect growth in average revenue per connection for their business customers on higher data rate DSL

[45] It also means that users who need to be continuously connected for convenience (e.g. Virtual Private Network users), despite not necessarily requiring a consistently high capacity, do not hold up valuable capacity (i.e. circuits) on an operator's network. Technology that could provide always-on access at lower data rates e.g. up to 144Kbit/s, could in principle be rolled-out to a larger proportion of the population with limited network upgrades using existing ISDN infrastructure (e.g. IDSL & AODI – always-on dynamic ISDN).

[46] See www.comreg.ie/docs/ComReg02122.doc

[47] www.ennis.ie

[48] www.thedigitalhub.ie

[49] Yankee Group, 'European Residential Broadband Takes Off', Jan 2002.

connections, where European business DSL revenues are predicted to exceed €8.5 billion by 2006[50]. This is likely to be a key driver in the roll-out of more advanced DSL technologies.

There are currently 30.6 million DSL lines world wide according to a recent benchmarking report[51]. The European Commission reported that, of the 10.79 million broadband customers in the EU, 7.52 million are retail DSL customers[52]. 80% of these DSL customers are served by incumbent operators and 4% are served by unbundled lines. In Ireland there were approximately 1900 DSL subscribers at the end of the third quarter of this year, 10% of which are non-incumbent lines[53]. Almost 3% of Europe's telephone lines are currently carrying DSL. Over 80% of these European DSL lines are classified as residential, although it appears they are mostly being used for business (SOHO) purposes[54].

7.2 Availability

It is estimated that between 70% and 90% of all lines within the European region are of suitable length for ADSL. Full coverage could, from a technical perspective, become available in other countries using, for example, rate adaptation techniques[55]. However, the quality and condition of individual copper local loops are also important factors in determining the suitability of lines for DSL. It is also important to realise that in Ireland, as in other countries, a number of potential customers are, and are likely to remain, outside of the reach of typical DSL technologies for some time to come (see Section 4.3).

The availability of DSL technology that can be easily installed by users without the need for a visit from a network operator's engineer is a significant advantage that has already been shown to impact on DSL take-up in France, Germany and the Netherlands[56] (see Section 4.4).

7.3 Incumbent Network Layout

The size of local exchanges, which dictates how many customers can be connected, is also an important factor contributing to the cost of DSL systems. In Ireland, compared to some other countries, the ratio of local exchanges to telephone lines is relatively high (over 1000 exchanges for 1.7 million lines – i.e. Ireland's exchanges are relatively small). This can make it less economic for operators to implement DSL in their smaller exchanges compared to a network with fewer, but larger, exchanges. Also in Ireland a large proportion of the population is located in rural areas which are beyond the range of typical DSL services. However, the costs of provisioning DSL are likely to continue to fall as technology develops, both in terms of equipment costs (falling at around 10% per year[57]), and through reduced floor space requirements (i.e.

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[50] Yankee Group, 'Revenue Sweet Spots in the Business DSL Market', March 2002.

[51] South Korea still has the largest amount of DSL lines (6.1 million), closely followed by the USA (5.8 million) and Japan (4.2 million – currently growing faster that South Korea and the USA). In terms of penetration South Korea is also the leader with over 26% of telephone lines converted to DSL – Source: Point Topic Ltd. December 2002.

[52] 8th Report on the Implementation of the Telecommunications Package, European Commission

[53] 'The Irish Communications Market Quarterly Review, December 2002', www.comreg.ie/docs/ComReg02106b.doc

[54] Source – DSL Forum August 2002

[55] Yankee Group 2002, "European Residential Broadband Takes Off"

[56] ibid

[57] Ovum, 'Broadband Network Roll-out in Ireland', September 2002 www.comreg.ie/docs/odtrovum.zip

smaller equipment requires less physical space[58]). Miniature DSLAMs are being trialled, for example in the UK by BT. It seems likely that such technology could play a significant role in deploying DSL in Ireland.

7.4 Regulation

Over and above issues associated with Local Loop Unbundling (LLU), there is an important role for regulators in helping to facilitate efficient and fair spectrum management schemes and ComReg has been active with operators in developing a frequency management plan. The first copper loop frequency management plan (CLFMP) for Ireland was published on the eircom website in April 2002, followed by an updated version in December 2002[59]. Future versions of the CLFMP are planned to include provision for VDSL and other technologies using spectrum above 1.1MHz. Existing systems such as ISDN must be accounted for when planning the type of DSL services to be deployed on a loop, and also the mix of DSL types which need to coexist in the copper access network.

LLU is an important regulatory issue. The aim here is to facilitate competition in the local loop and is therefore important for the widespread roll-out of DSL in Ireland. For more information on Local Loop Unbundling please consult the ComReg website[60].

[58] Co-location costs can be expensive for installations serving very few subscribers (e.g. 10 subscribers) – Ovum, 'DSL Business models for exploiting the local loop'.

[59] www.eircomlab.com/clfmp/CLFMP_Iss2.pdf

[60] www.comreg.ie/docs.asp?Type=Category&Category=Local+Loop+Unbundling&Image=images/unbundling.gif

8 Conclusion

DSL is emerging in Ireland as an important broadband access technology. It could potentially deliver broadband services to a large proportion of the Irish population, making more efficient use of existing installed copper in local loops and extending its useful life. The biggest issue currently appears to be retail pricing, although there are also issues relating to technical availability. For example, some users are located too far away from a DSL enabled local exchange. In the case of some advanced users, current DSL data rates may not be sufficient to meet their needs, and they may have to consider alternative access solutions (e.g. optical access via dedicated leased lines).

However, it is clear that technological developments could make the implementation of high capacity DSL-based services more cost effective. This will open up opportunities that should lead to better services for users and new sources of revenue for operators. There are a variety of DSL technologies and standards becoming available from which operators can choose to deliver services to users with different needs. Growing penetration of higher capacity access links, such as SHDSL and VDSL, will necessitate operators rolling out fibre links closer to end users.

It is important to recognise that DSL, key though it is, is just one of the access technologies needed to deliver broadband services in Ireland. Other technologies, such as cable, FWA, satellite, optical and 3G, probably all have significant roles to play.

A list of useful references is given in Annex 9.9 for readers seeking more information on DSL services and technologies.

9 Annexes

9.1 DSL Frequency Use

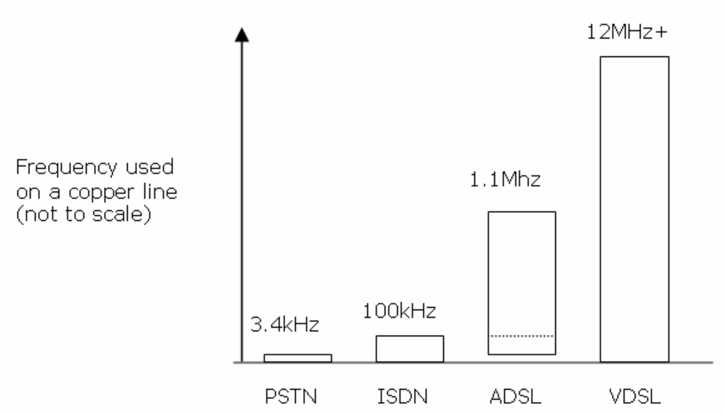

Figure 1 – Illustration of greater frequency spectrum used by DSL services
Note: The ADSL signal starts at a frequency above those occupied by the PSTN signal, allowing ADSL and PSTN services to share the same line. In some cases services can be adapted to occupy contiguous segments of spectrum, e.g. ADSL starting at 100kHz (indicated by the dotted line) can be 'stacked on top' of an ISDN signal enabling both to be carried simultaneously on a single line.

9.2 DSL Network Diagrams

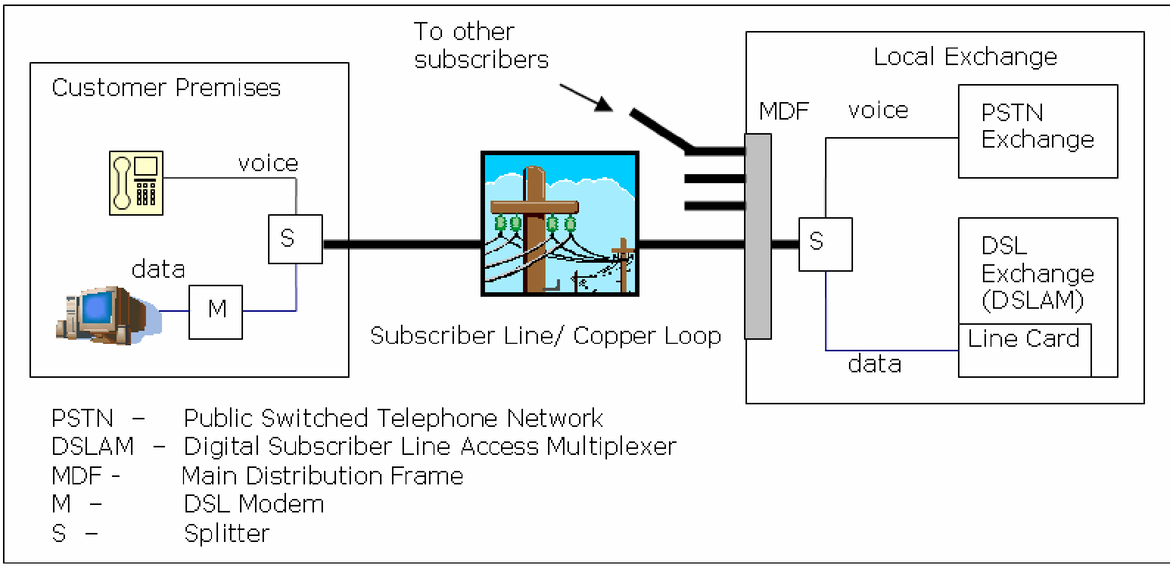

Figure 2. – Simplified ADSL network diagram showing the use of splitters.

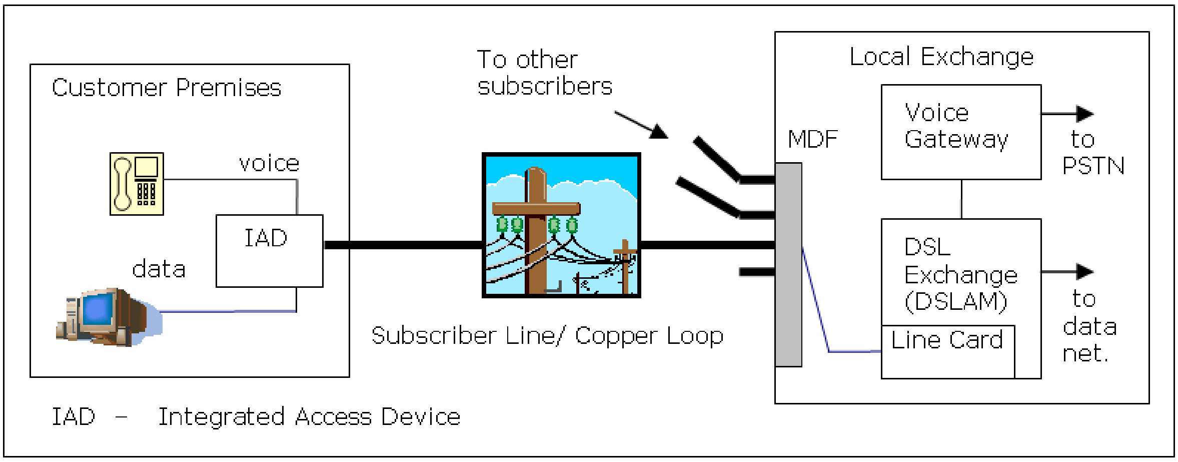

Figure 3. – Simplified DSL network diagram showing integrated voice and data (e.g. SHDSL).

9.3 Main DSL Network Elements

Below are brief descriptions of some of the main DSL elements.

DSL Access Multiplexer (DSLAM)*:* controls and adapts communications for transmission over the local loop.

Line card: The DSL modem element of a DSLAM that interfaces between the copper line and the DSLAM transmission function. It is responsible for transmitting and receiving the physical DSL signals.

Splitter: used to separate the low frequency PSTN portion of a signal from the higher frequency DSL portion when both are present on the same line.

DSL Modem: performs some similar functions to the line card, at the customer's premises. It is used to convert information to and from the DSL signal. An Integrated Access Device (IAD) is a more advanced piece of customer premises equipment that can integrate different types of communications applications and services onto the same DSL signal such as voice over DSL and Internet access.

Voice gateway: used to connect digital telephony traffic (e.g. VoIP) between the DSLAM and PSTN network.

Copper Local Loop: the physical connection between a customer's premises and the local exchange. A copper loop will consist of at least one pair of copper wires. Local loops can range in lengths typically up to 4km in urban areas and up to 7km in other areas (although some lines may exceed this in rural areas).

Main Distribution Frame (MDF): used to connect physical copper wires in a local exchange.

9.4 Different Types of DSL

Each of the main types of DSL are summarised below:

IDSL (ISDN DSL): This type of DSL delivers basic rate ISDN[61] type services up to data rates of 144kbit/s.

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[61] Integrated Services Digital Network

HDSL (High bit rate DSL): A symmetrical service operating at data rates up to 2Mbit/s. These systems require two or three copper pairs to operate and are typically used to provision 2Mbit/s leased lines (E1).

SDSL (Symmetrical DSL): A symmetrical service operating at data rates up to 2.3Mbit/s.

SHDSL (Single pair High-speed DSL): A symmetrical service operating at data rates up to 2.3Mbit/s over a single copper pair. SHDSL is a standardised and improved version of SDSL.

ADSL (Asymmetrical DSL): An asymmetrical service capable of operating at downstream data rates of up to 6Mbit/s and upstream data rates up to 640kbit/s. ADSL operates independently from voice services and the two can therefore coexist on the same subscriber line with the use of a splitter (see Figure 2).

ADSL Lite (G.lite): A lower data rate version of ADSL targeted for the residential market with downstream rates up to 1.5Mbit/s and upstream rates up to 512kbit/s. ADSL lite is designed for easy installation. ADSL lite eliminates the need for a splitter at the customer's premises reducing equipment and installation costs. Splitter-less technologies are being deployed less since the emergence of low-cost filters (i.e. splitters) that enable self-installation of technologies such as ADSL.

ADSL2 (ADSL+): An updated version of ADSL with some enhanced features and more flexibility.

RADSL (Rate Adaptive DSL): This is a flexible version of DSL that can be used to reach customers at distances beyond the reach of ADSL on a given line.

VDSL (Very high data rate DSL): VDSL is a developing type of asymmetrical DSL with potential downstream data rates up to 54Mbit/s and upstream rates of up to 6.6Mbit/s or 26Mbit/s. VDSL achieves such high data rates by using a far greater amount of spectrum on a copper cable, i.e. up to 12MHz. The particular details of the VDSL physical layer (modulation and line code) are yet to be standardised[62] although other parts of the technology have been standardised in ITU G.993.1.

Other types of DSL include CDSL (consumer DSL), UDSL (Unidirectional DSL), and HDSL2.

9.5 Dynamic Spectrum Management

Since not every customer will want DSL services, and some will require different types of DSL service (e.g. SHDSL or ADSL) there will be a need for various types of service (e.g. PSTN, ISDN, ADSL) to coexist side by side in the same bundles of cables leading to a local exchange. Furthermore, with LLU, different operators using different variants of DSL and other services may have to share the same bundles of cables.

Currently DSL systems of various types are able to co-exist on the same bundles of cable through careful spectrum management, whereby individual types of DSL systems must operate within certain constraints know as spectrum masks. These constraints are designed to mitigate interference (cross-talk) between the different DSLs and other services, whilst maximising the throughput on each.

[62] There are two main competing approaches; a multi-carrier scheme (DMT), and a single-carrier scheme (CAP/QAM).

When sufficiently developed, a technique called 'dynamic spectrum management' (DSM[63]) could potentially make more efficient use of the available spectrum on a bundle of cables. This approach could enable the characteristics of individual DSLs to be dynamically adjusted depending on the environment they are operating in (i.e. what signals are on adjacent cables). This would achieve even higher throughput levels and further reach without additional interference. DSM is still under research and development and is not currently part of the CLFMP.

9.6 Applications

ADSL was originally developed with the aim of providing video on demand and interactive TV transmission to customers[64] – video over DSL. However, during development of DSL the Internet emerged as a major application and hence DSL products were re-targeted with this application in mind. DSL technology can be used to deliver high speed Internet access, enabling users to access web pages and applications more quickly. Internet access (i.e. web browsing) is typically asymmetrical in nature in that users generally download far more information than they transmit. ADSL is well suited to this type of asymmetrical application.

Applications such as peer to peer, where users need to transmit and receive similar amounts of information, require symmetrical services such as SHDSL. The extra capacity provided by some DSL technologies can also, for example, enable multiple users to access simultaneously different Internet pages in a single household. If there were a large proportion of users with high speed access, it is likely that this would encourage content developers to place more enriched content on the Internet. Applications such as on-line education, tele-working, and on-line gaming would all benefit from increased broadband Internet access.

Voice services have so far generally been delivered separately from DSL on the same copper local loop using splitters that can discriminate between the signals (see Figure 2 in Section 9.2) Some DSL systems can deliver voice services (without the need for splitters) using 'voice over DSL' (VoDSL). This involves a voice gateway connecting the DSL domain (i.e. ATM) and the PSTN domain (TDM, SS7). Alternatively voice can be delivered over IP (VoIP) over DSL. This requires voice gateways to interwork between the VoIP and PSTN networks at some point. Higher layer protocols can be selected to provide the necessary quality of service/class of service for different users (e.g. ATM or IP).

9.7 Glossary

ADSL	Asymmetrical Digital Subscriber Line
ANSI	American National Standards Institute
AODI	Always-On Dynamic ISDN
CAP	Carrierless Amplitude/Phase
CLFMP	Copper Line Frequency Management Plan
DMT	Discrete Multi-Tone
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer (Module)
DSM	Dynamic Spectrum Management
HDSL	High bit-rate Digital Subscriber Line
HF	High Frequency
IDSL	ISDN Digital Subscriber Line
ISDN	Integrated Services Digital Network
ITU	International Telecommunications Union
LLU	Local loop un-bundling

[63] See "Dynamic Spectrum Management for Next-Generation DSL Systems", IEEE Communications Magazine, October 2002.

[64] ITU-D, "Report on DSL technologies", 2002

PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
RADSL	Rate Adaptive Digital Subscriber Line
SDSL	Symmetrical Digital Subscriber Line
SHDSL	Single-pair High-speed Digital Subscriber Line
VDSL	Very high data rate Digital Subscriber Line

9.8 List of Relevant standards

Global
ITU (International Telecommunications Union) – Study group 15, SG13 for wider architectural context. 1997
G.991.1 – High bit rate DSL (HDSL)
G.991.2 – Single-Pair High bit rate DSL (SHDSL)
G.992.1 – Asymmetrical DSL (ADSL)
G.992.2 – Splitterless Asymmetrical DSL (ADSL) – also known as ADSL lite
G.992.3 – ADSL2
G.992.4 – Splitterless ADSL2
G.993.1 – Very high data rate DSL (VDSL)
G.994.1 – Handshake procedures for DSL
G.995.1 – Overview of DSL recommendations
G.996.1 – Test procedures for DSL
G.997.1 – Physical layer management for DSL

European
ETSI (European Telecommunications Standards Institute) – 1992, TM3, TM6
TS 102080 – ISDN BA
TS 101135 – HDSL
TS 101524 – SDSL
TS 101388 – ADSL
TS 101270 – VDSL

US
TIA (Telecommunications Industry Association) – specification for a network gateway, TR41.5
IEEE (Institute of Electrical and Electronic Engineers) 802.14 (VDSL)

9.9 Further Information on DSL

For further information and advice on DSL and related matters, see:

Advice:
www.techcentral.ie – Irish web site for technology related issues

www.dcmnr.gov.ie – Department of Communications Marine and Natural Resources: Information on government policy and telecommunications initiatives

www.chambersireland.ie Chamber of Commerce: Information and research for SMEs.

www.enterprise-ireland.com/connect-supplier-search.asp - Business listing

www.dataprivacy.ie - Information on data protection

www.adslnow.ie – Irish DSL information website

Service Providers:
http://mmm.eircom.ie/mouse/faster/istream.htm - Eircom's DSL product.

www.esatbt.com/esatcom/homepage/products_solutions/access/dsl.htm - Esat BT's DSL product.

www.colt-telecom.ie/colt_micro/frameset_ie.php?sid=14&pid=140105 – Colt Telecom

Projects and Initiatives:
www.ennis.ie – Information Age town in Ennis.

www.thedigitalhub.com – Government initiative to create an international digital enterprise area in Dublin.

If you are considering upgrading your business IT and communications systems, you may want to consult a specialist advisor:
www.goldenpages.ie/busListResult.asp?SubEle=Telecommunications&listEle=Telecommunications&products=Telecommunications&town=&county=All&image1.x=37&image1.y=21