2 Broadband and why it matters

2.1 What is broadband?

Broadband provides users with always-on, high-speed connections to access the internet and transfer data. The term 'broadband' has outgrown original narrow definitions based on specific data transmission speeds and is now widely used "*simply as shorthand for high speed Internet access*"[1]. The extensive and growing variety of broadband products available in EU member states – for example, in terms of transmission speeds – demonstrates the need to maintain a flexible definition of broadband in any market analysis. This should be based on the notions of 'high-speed' and 'always on', which differentiate broadband services from narrowband dial-up access to the internet, rather than specific minimum thresholds for transmission speed. Any definition should reflect the fact that it is possible to offer fundamentally identical products from the perspective of the end user over different delivery platforms.

As observed in the Commission's eEurope 2005 Action Plan, there is no universally recognised definition of broadband.[2] The technical term 'broadband' was originally defined by the ITU as transmission capacity that is *faster* than primary rate ISDN (*i.e.* 1.5 or 2 Mbps)[3]. However, it is now widely used by network operators marketing DSL, cable modem and other access services to users starting at speeds of 256 Kbps or even 128 Kbps. OECD governments have attached "*a wide variety of meanings*" to broadband in particular policy discussions.[4] For example, in a 2001 task force report, the Italian government drew a distinction "*between those, such as the FCC in the United States, who have defined broadband exclusively in terms of transmission capacity (number of kbit/s) and those, as in Canada, who have primarily based their definition on the type of services that can be provided.*"[5]

For the purposes of benchmarking comparisons, Paltridge (OECD, 2001) defines a minimum threshold for broadband of 256 Kbps for downstream (i.e. data transmissions *to* the user) and 64 Kbps for upstream (*from* the user). This definition has become widely used in statistical exercises and forms the basis for much of the data referenced in this book. Paltridge's downstream threshold is loosely related to an earlier FCC definition, which set a threshold of 200 Kbps, or (in the agency's view) roughly enough to allow users to transmit full-motion video or change web pages as if they were turning the pages of

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[1] OECD (2001), page 6.

[2] European Commission (2002a), page 7.

[3] ITU-T (1997).

[4] OECD (2001), page 6.

[5] Italian Government (2001), page 10.

a book. The much lower upstream threshold reflects the commercial reality of many residential services supplied by asymmetric digital subscriber line (ADSL). However, as Paltridge points out, defining a "*. . . minimum threshold for 'broadband' only really takes on importance if a government has a specific service in mind that requires a certain level of network performance.*"[6]

There has been significant discussion as to whether there is a distinct market for broadband services that is separate from narrowband internet access. In Box I, we argue that although there is evidence of one-way substitution from narrowband to broadband and some linkages in pricing, there is a distinct market for broadband. This reflects the fact that broadband offers users significant benefits not available via narrowband; in particular: faster access to the Internet; access to high bandwidth applications, such as music, video and games; an always-on connection; and the ability to use the Internet without tying up a voice line. Regulators across OCED countries have adopted similar positions; for example:

□ In the United States, the Federal Communications Commission (FCC), Federal Trade Commission (FTC) and Department of Justice (DOJ) have all made independent rulings that the provision of residential high-speed Internet access services is a distinct market in its own right.[7]
□ In its 2002 annual report, Spanish regulator CMT stated: "*la CMT ha* considerado *la existencia de un mercado de servicios de acceso de banda ancha claramente diferenciado del de la banda estrecha*" ["the CMT considers that there is a market for broadband access clearly different to that of narrowband"].[8]

Since 2002, there has been a significant expansion of broadband product portfolios by operators in most European broadband markets, which is consistent with the maturing of the market and movement along the standard product life cycle. By differentiating products on the basis of transmission speed and/or capacity, pricing and other characteristics, operators are able to serve residential and business customers with differing needs at the low and high-ends of the market. Such differentiation can be expected to stimulate further growth in demand for broadband services; a 2003 report by IDC identified this trend as a "*key driver for the European broadband market*"[9]. Therefore, it is important

[6]OECD (2001), page 6.

[7]See for example: FCC – Memorandum Opinion & Order, Applications for Consent to the Transfer of Control of Licenses and Section 214 Authorizations by Time Warner Inc. and America Online, Inc., Transferors, to AOL Time Warner Inc., Transferee, 16 F.C.C. Rcd. 6547, 56 (2001); FTC – Complaint, America Online, Inc. v. Time Warner, Inc., Dkt. No. C-3989 (FTC filed Dec. 14, 2000) 21; DOJ – Competitive Impact Statement at 9, United States v. AT&T Corp., Civil No. 00-CV-1176 (D.D.C. filed May 25, 2000).

[8]CMT Annual Report, 2002, page 50.

[9]IDC (2003).

from a regulatory perspective that any definition of broadband is flexible enough to accommodate the full variety of products available.

Any definition of broadband should also be platform-neutral to the extent that it is possible to offer a variety of broadband products over different delivery platforms that offer users very similar experiences. For example, although the technologies associated with DSL and cable are quite different from one another, both offer comparable bandwidth and always-on connectivity, and are thus largely functionally equivalent from the perspective of users of data services. Although PSTN and cable networks have historically offered quite different services, there is now increasing convergence with similar service bundles being offered over different underlying networks. A platform-neutral approach is consistent with the framework adopted for the *e*Europe 2005 Action Plan, which "*promotes a multi-platform approach to broadband deployment, driven by strong competition between services and networks.*"[10]

Box I: Is broadband distinct from narrowband?

The substitutability between narrowband access and broadband access depends on the value that broadband users place on the advantages of broadband access. If enough consumers value broadband's unique advantages sufficiently that they would not switch in large numbers to narrowband access in the face of a small but significant increase in the price of broadband, then the two types of access are not demand substitutes.[11]

Broadband offers three main advantages over narrowband access:

- □ it decreases time costs, as an 'always on' connection provides instant access to the Internet (whereas dial-up requires wait time and lines may occasionally be engaged) and higher bandwidth enables faster download of webpages and files;
- □ it enables access to high bandwidth applications, such as streaming video and real-time radio, home networking, customised Internet video and audio libraries (such as Yahoo's LaunchCast), interactive gaming and high-speed telecommuting; and
- □ unlike narrowband, a broadband connection does not tie up a consumer's phone line, allowing inbound and outbound voice calls.

We consider the value that consumers place on each of these broad attributes in turn:

1. *Time costs*. Consumer surveys suggest that consumers do attach significant benefits to time savings provided by broadband. For example, a survey

[10] European Commission (February 2003a), page 6.

[11] See Annex III for a brief introduction to demand substitutability and market definition.

by Enders (2003) found that 41% of UK internet users considered "faster Internet experience" to be the main advantage of broadband. There is little empirical evidence on how much users value this extra speed. A study by Varian (1999) observed a "*very low willingness-to-pay for broadband and very low values for time*" (the average user exhibited a time cost of less than 1 US cent per minute).[12] However, this study is now somewhat out of date and, as Varian acknowledged, the survey sample may have been skewed by the reliance on volunteers (many were students) who may be individuals with a relatively low opportunity cost of time and therefore non-representative of Internet users in general. It is reasonable to expect that those consumers with the highest time cost of money will be among the most likely to purchase broadband services. Roughly 17% of the subjects exhibited a time cost of five US cents per minute ($3 per hour) or greater.[13]

2. *Access to additional content*. Consumer demand for much of the additional content and services available over broadband remains unproven in most OECD countries. In the Enders (2003) survey, just 2% of Internet users cited interactive content to be the main advantage. However, demand for such applications appears to be 'sticky' in that once consumers adopt broadband and begin using advanced functionalities (such as web browsing at speeds equivalent to turning a page of a book), they value broadband more than they did when they first adopted.[14]

3. *Phone line usage*. A consumer who uses narrowband service cannot make or receive telephone calls from her residence while she is connected to the Internet unless she also purchases a second telephone line. A survey by the Yankee Group found that 70% of U.S. households with two or more telephone lines subscribed to a second line to accommodate Internet access.[15] Costs for a second telephone line can be high. For example, in the United States, the cost of a second line in 1999 varied from US$7.70 to US$47.62 per month, plus installation charges.[16] For the United Kingdom, Enders points out that the cost of an additional line plus the cost of dial up access is approximately the same as getting a broadband connection.[17] Of course, not all narrowband customers choose to purchase a second line; many use a mobile telephone for voice communications while connected to the Internet or simply go without telephone services. Nonetheless, the use of narrowband service imposes a cost on consumers by tying up a residential landline phone line. Enders (2003) found that 41% of consumers considered the ability to use the phone and be online at the same time to be the main advantage of broadband.

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[12] Varian (1999).

[13] Varian notes that his methodology provides only a "*rough-and-ready, nonparametric estimate.*"

[14] Office of Technology Policy, U.S. Dept. of Commerce (2002).

[15] Yankee Group (2002).

[16] Hausman, Sidak and Singer (2001).

[17] Enders (2003).

Overall, the benefits to users of broadband relative to narrowband appear substantial, and are likely to increase for many users once they subscribe to broadband. It thus seems unlikely that a hypothetical monopolist of broadband service in a particular local market would need to control narrowband services to benefit from a small but significant and non-transitory price increase above cost. This implies that broadband and narrowband are distinct markets. This conclusion is supported by academic analysis of U.S. internet access prices. For example, Hausman et. al (2001) notes that data on the price variations of narrowband in different U.S. geographical markets demonstrates that narrowband service is a separate relevant market from broadband service: "*[t]he straightforward observation is that narrowband access prices differ by a factor of over 300 percent, while broadband access prices do not vary in any way with these differences.*"[18]

This conclusion does not deny that potential substitution from narrowband to broadband exists. There is a vertical relationship between the two markets such that all consumers can be expected to view broadband as superior but vary in the amount that they are willing to pay for the higher quality good; hence, broadband prices act as a constraint on narrowband prices in the sense that many narrowband users might switch to broadband if the price differential between the services were small enough. However, narrowband pricing constrains broadband pricing only to the extent that the size of the price gap acts as an initial constraint on take-up of broadband. Forrester Research argue convincingly that the decline in the broadband premium over dial-up – the European average fell from 178% in 2001 to 101% at end-2002 – has been a key factor spurring take-up in Europe in 2002.[19] Various consultants have talked about threshold prices at which broadband becomes a viable mass-market alternative to dial-up; according to Forrester, this point was reached when the lowest prices available fell to around 30 euros.

Arguably, the distinction between narrowband and broadband is becoming less clear with the emergence of new entry-level broadband products, which feature low-bit-rates or usage restrictions. The objective of these products appears to be "*to tempt consumers away from dial-up, aiming to convert them to pricier, faster products later.*"[20] Examples (taken in August 2003) include: KPN's 256 Kbps ADSL product, an ADSL offer from Telecom Italia's tin.it ISP at 27.95 euros per month which has a 20-hour usage cap, and UK cable company ntl's 150 Kbps low-end offer. The presence of these entry level broadband products might increase interaction between the pricing of broadband and narrowband to the extent that this leads to a chain of substitutable products, but this is yet to be seen.

[18] Hausman (2001) page 6-7.

[19] Forrester (June 2003a).

[20] Forrester (June 2003a).

Table 1: Broadband forecasts for Western Europe

Forecaster	Year	Broadband subscribers	Broadband revenues per annum
Datamonitor[21]	2006	41 million	US$ 16bn +
IDATE[22]	2007	65-75 million	Euro 22.4bn
IDC[23]	2007	62 million	US$ 27bn
Forrester[24]	2008	49.7 million	na
Strategy Analytics[25]	2008	63 million	na

2.2 The importance of broadband to the EU economy

According to many industry reports, broadband access will be one of the key sectors underpinning productivity and economic growth in the EU over the next five years. The sector is both important in its own right and, as a facilitator of faster and more efficient data transmission and internet access, a key input into other economic sectors.

Independent forecasters project rapid growth for broadband subscribers and revenues over the next five years. In Table 1, we provide a snapshot of forecasts for subscribers and revenues across Western Europe, made in 2003 and 2004. The most conservative, from Forrester and Datamonitor, predict that there will be 38 million and 41 million European households, respectively, using broadband by 2006, up from 10.3 million at end-2002. Forecasts for direct revenues range from at least 14 billion euros in 2006 up to 24 billion euros by 2007. Revenues for direct access and content will be dwarfed by the indirect benefits of faster internet access, for example through greater use of e-commerce and spread of e-government.

Academic research provides strong backing for this assertion that new communication services can lead to very large increases in consumer welfare, through meeting needs that would otherwise go entirely unmet. For example, Hausman (1997) estimated that the consumer welfare gain from voice messaging services introduced in the United States in 1990 would have been 1.27 billion US dollars by 1994 if the FCC had not delayed in authorising such service. He further estimated the gains from the introduction of cellular telephone services at 50 billion dollars a year.[26] Goolsbee (2001) estimates pre-tax consumer surplus

[21] Datamonitor (2003), page 5-7.
[22] Idate (2002).
[23] IDC (2003).
[24] Forrester (2003a).
[25] Strategy Analytics (2003).
[26] Hausman (1997), page 2.

from the introduction of broadband in the United States at 700 million dollars per year as of mid-1999, even though penetration at that point was only 2-3% of on-line users. Unfortunately, there are no recent studies estimating the direct contribution of broadband to consumer welfare and none for EU countries. However, inferring from the results of these studies, one would expect a value already in the many billions of euros.

These estimates of the value of broadband services are based on adding together individual consumers' willingness to pay for services. Various external benefits may also arise that are not reflected in end-customers' willingness to pay, particularly if there are network effects, which would not be privately valued. For example, consumers' decisions to use e-commerce to buy goods and services may lead to benefits for suppliers in terms of reduced cost and greater efficiency. The adoption of new technologies and their faster diffusion also benefits equipment manufacturers, via increased demand. Taking all these potential gains into account, Crandall, Jackson and Singer (2003) estimated that the total annual consumer benefit from broadband in the United States would be between 64 and 97 billion US dollars per year if 50% of U.S. households adopted broadband, and could be more than 300 billion US dollars per year if broadband were to achieve universal diffusion in the United States. The authors also found that the ubiquitous adoption of current broadband technology would increase total U.S. GDP by 180 billion US dollars and create 61,000 new jobs per year, and that the ubiquitous adoption of more advanced access technologies (such as FTTH or VDSL) would sustain 140,000 new jobs per year.[27] Given the similar size of the U.S. and EU economies, it is plausible to assume that the benefits to Europe could be of a similar magnitude.

Given the substantial benefits available from broadband development, it also follows that delays in broadband deployment and thus take-up could have significant opportunity costs. In particular, poorly designed regulation can have a detrimental impact on investment and competition, with direct negative implications for consumer welfare and even larger indirect effects for the wider economy. For example, Hausman (1997) estimates the total cost of FCC regulatory delay on the U.S. mobile phone market at around 100 billion US dollars.

The importance of the broadband market has been recognised in numerous documents and speeches made by governments and international bodies in recent years, reflecting not just the utility of services to end-users, but also broader social benefits. For example:

- **ITU:** "*Broadband has been referred to as the infrastructure of the knowledge economy. Countries around the world have nominated broadband networks as crucial infrastructure for achieving their social, economic and scientific goals.*"[28]

[27] Crandall, Jackson and Singer (2003).
[28] ITU (2003), page 3.

- **OECD:** "*If, as many believe, new communication tools such as the Internet and wireless networks boosted growth in the latter half of the 1990s, and softened the current cyclical downturn, then the next steps toward broadband access are of critical importance that go beyond the communications sector.*"[29]
- **European Commission:** "*Distance education (using e-learning), access to government services (e-government), healthcare (e-health), entertainment, videoconferencing, e-commerce, etc. become more practical and often feasible only through the high speed provided by broadband access. . . . The adoption of these services into our daily life, and the opening of new markets, can improve quality of life, increase productivity and stimulate innovation.*"[30]
- **Ireland, ODTR:** "*[T]he development of a vibrant broadband sector has the potential to not only stimulate growth in a new set of higher-value industries, but to open up new possibilities for all citizens, irrespective of geographic location.*"[31]
- **UK government:** "*The rapid roll out of high bandwidth technology is clearly a prerequisite to a successful UK e-commerce sector.*"[32]
- **U.S. FCC:** "*The widespread deployment of broadband infrastructure has become the central communications policy objective today.*"[33]
- **Canadian Minister of Industry:** "*Broadband can stimulate innovation and improve the quality of life for all Canadians, especially those in First Nations, northern, rural and remote communities. It is applications in areas like distance education, telemedicine and e-business that will touch the everyday lives of communities and advance economic development.*"[34]
- **South Korea, Ministry of Information and Communication:** "*Broadband Internet, which is 32 times faster than that of the dial-up modem on average, can not only utilize the idle facility of the backbone network, but also promote the related equipment and component industries, nurturing a positive economic cycle in the future. In addition, the high-speed broadband Internet service will pave the way for multimedia contents, application services and e-commerce to prosper.*"[35]

At a minimum, EU governments should provide a framework for broadband that does not impede rollout. There may also be a case for more active government promotion of broadband, given the scope for realising positive externalities for the economy at large not reflected in customers' willingness to pay for services. However, the impact of any regulatory intervention on incentives for

[29] OECD (2001), page 4.

[30] European Commission (February 2003a), page 6.

[31] ODTR (2002).

[32] PIU (1999), page 63.

[33] Powell (2001).

[34] Industry Canada (2003).

[35] IT Korea (2002).

both industry players and consumers need to be carefully thought through. Measures that impede or slow the development of broadband services may have very large costs, even if these are not immediately evident.

2.3 Broadband delivery technologies

There are many different technologies currently available that can be used for delivering broadband to both residential customers and businesses. These include DSL, cable, fibre, satellites, fixed wireless access, electrical power lines, mobile communications, wireless LAN and free-space optics. All these technologies have relative strengths and weaknesses, for example, in relation to maximum transmission speeds or vulnerability to interference and capacity constraints. Nevertheless, the types of user experience that they offer – once infrastructure is in place – are sufficiently similar that significant numbers of customers are likely to find services delivered by these different technologies closely substitutable.[36]

In the remainder of this subsection, we describe the various technologies for delivering broadband, highlight their strengths and weaknesses and discuss their potential development over the medium term. Our main observations are as follows:

- The current prevalence of ***DSL*** and ***cable*** is based on their use of existing infrastructure and first-to-market status, rather than any technological superiority. Actual transmission speeds are often quite low relative to some other platforms, although they may improve as technological advances are implemented.
- ***Fibre-to-the-home (FTTH)*** offers far superior speeds to standard DSL or cable. Although expensive to deploy if new trenches need to be dug, it can be cost effective in urban areas, especially if consumer use of bandwidth-hungry applications takes off. However, the distinction between fibre, and cable and DSL technologies is becoming blurred, as the latter undertake increasing deployment of fibre closer to the end customer and upgrade their distribution capacity.
- High deployment costs and problems with upstream connectivity mean that ***satellite*** is currently not cost effective as a mass market alternative to DSL and cable, except for rural areas, where the cost of building fixed infrastructure is prohibitive.
- ***Fixed wireless access (FWA)*** has now been available for several years in many European countries but as yet has only found a market as a niche solution for businesses. It still has potential to become a mass market technology, particularly if the costs of equipment were to fall. Over such a timescale, it faces being overtaken by more flexible WLAN and mobile technologies.

[36]For further discussion of this point, see Section 3.2, which compares broadband offers available in EU markets on different platforms.

- □ Owing to their ubiquity, electric ***power lines*** have potential as a mass market alternative to DSL or, more likely, a cost-effective way of extending broadband to rural areas. However, some technical and regulatory obstacles apparently need to be overcome. The longer the delay in the mass market deployment in European countries, the less likely that it will gain critical mass.
- □ ***WiFi*** (wireless LAN) technology currently provides hotspot internet access services, and is starting to be used to provide broad coverage public access networks in both urban and rural areas. This is a mature, cost effective and low risk technology. Many laptop computers are sold with wireless LAN functionality already built in.
- □ ***3G mobile*** is being deployed by MNOs across Europe. This will ultimately give the mobile telephone customer base an alternative means of broadband access;
- □ ***'new mobile'*** technologies can provide mobile broadband services, for example, bringing cell structure and cell handover to wireless LANs that currently permit only nomadic use. They can use a variety of different radio spectrum, including unused spectrum that many European 3G licensees hold. Commercial services are already being rolled out (e.g. in Australia) with bandwidth and pricing comparable to DSL services.

Table 2 provides a rough visual summary of the relative strengths and weaknesses of these technologies.

2.3.1 Digital subscriber line (DSL)

DSL technologies make use of existing telephone lines to deliver voice, data, and video traffic simultaneously at high speed. An 'always-on' connection is established between a modem at the user end and a DSL access multiplexer (DSLAM) at the local exchange. Using advanced modulation and signal processing techniques, data is carried over existing twisted pair copper wire at frequencies significantly higher than those used for voice traffic. Both upstream (from the user to the exchange) and downstream transmission is possible. Voice and data signals are separated using a line splitter, allowing simultaneous use of lines for narrowband voice telephony and broadband access for PCs or television set-top boxes.

DSL can be deployed in a number of different ways, for example:

- □ *Asymmetric DSL (ADSL)*. This is the most common form of DSL and is primarily targeted at the residential market. With an ADSL connection, the data channel is split into a number of sub-channels, creating flexibility in the way that data is allocated across the breadth of the connection. Much higher speeds are achievable for downstream (up to 8 Mbps) than for upstream (up to 1 Mbps), which is convenient for most common uses of the Internet, such as web surfing and file downloading.

Table 2: Relative strengths and weaknesses of broadband delivery platforms*

	DSL			Cable	FTTH	FWA	Satellite	WLAN/WiFi	Powerline	PPL/FSO	Mobile	
	ADSL	SDSL	VDSL								3G	Beyond 3G
Deployment												
Current availability	✓✓✓	✓	×	✓✓	✓	✓	✓	✓	××	××	✓	××
Suitability for urban areas	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
Suitability for rural areas	×	×	××	××	××	✓	✓✓✓	✓	✓✓	×	✓	✓
Mobility	××	××	××	××	××	×	×	✓	××	×	✓✓✓	✓✓✓
Quality of service												
Transmission speeds	Up to 8 Mbps	Up to 2 Mbps	Up to 52 Mbps	128 Kb - 10 Mbps	2–100 Mbps	2–40 Mbps†	300 Kb – 2 Mbps +	Up to 54 Mbps	Up to 45 Mbps	Up to 1 Gbps	Up to 2 Mbps	Up to 30 Mbps
High-speed service	✓	✓	✓✓✓	✓	✓✓✓	✓✓	✓✓	✓	✓✓✓	✓✓✓	×	✓
Symmetric speeds	NO	YES	NO	YES	YES	YES	YES‡	YES	YES	YES	YES	YES
Degradation due to:												
capacity / shared lines	NO	NO	NO	YES	YES	NO	YES	YES	YES	NO	YES	YES
length of line or link	YES	YES	YES	NO	NO	YES	NO	YES	NO	YES	YES	YES
Costs & development												
Maturity of technology	✓✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	×	××	✓	×
Costs: equipment	✓✓✓	✓✓	×	✓✓✓	×	✓	✓	✓	✓	×	××	××
Costs: customer installation	✓✓[1]	✓✓[1]	×	✓✓✓[1]	×	✓✓	✓✓	✓✓	✓	✓✓	✓✓✓	✓✓✓

Source: DotEcon, September 2003; *This is a rough approximation only, where ✓✓✓ indicates the strongest and ×× the weakest; †At mid-range bandwidths; ‡Two-way satellite only; [1]Assumes that copper or cable connections are already in place; otherwise installation costs would be much higher, as is the case for VDSL or FTTH.

- *Symmetric DSL (SDSL)*. Standard SDSL systems provide symmetrical upstream and downstream speeds of between 160 Kbps and 2 Mbps. It is generally deployed for small and medium-sized enterprises (SMEs) who require significant two-way bandwidth. G.SHDSL (single pair high-bit rate DSL), a new system that allows symmetric speeds of up to 2.3 Mbps, has been standardised by the ITU and is increasingly being deployed in Europe and the United States.
- *Very high-speed DSL (VDSL)*. Even higher bandwidth (up to 52 Mbps downstream and 16 Mbps upstream) can be achieved using VDSL technology. Unlike ADSL, this system makes use of a fibre optic connection which must be run to the curb or neighbourhood, such that only the final portion of the local loop is copper. A VDSL transceiver and gateway are placed at either end of the copper wire, the latter converting the data for onward transmission over fibre. Owing to the cost of laying new fibre, VDSL is most suited to multi-unit sites, such as offices and apartment blocks.

The main advantage of DSL technologies over other broadband delivery platforms are their use of ubiquitous, copper line infrastructure. In theory, the speeds achievable over DSL rival most other delivery platforms, with the exception of fibre. However, actual bandwidth is highly dependent on line quality and length of the local loop; the maximum line length for ADSL is about 5,500 metres, while for VDSL it is just 1,200 metres. Consequently, while DSL generally works well in urban areas, it is often not suitable for rural areas, where the distance from the local exchange is a constraint on providing service to a large proportion of customers. Additionally, the 'loop' consists of many segments of copper with different vintages and other characteristics, and the DSL speed is constrained overall by the weakest link in the chain. Most customers thus enjoy speeds well below the theoretical maximum.

Relative to other broadband delivery platforms, DSL is already relatively mature, with network operators enjoying the benefits of economies of scale in equipment manufacturing associated with mass deployment worldwide. Over the next five years, technological innovation will likely see lower costs, especially in relation to DSLAMs, and some further advances in potential bandwidth obtainable over copper wires. Where it is cost effective, DSL operators may also move to upgrade parts of the copper loop with fibre.

2.3.2 Cable

Like ADSL, cable broadband delivers an always-on high-speed internet connection. In a typical cable network, data is transferred between a cable modem at the user end and cable modem termination system at the local distribution hub. Line splitters are used to enable simultaneous use of data, television and (where available) voice, although with some networks (e.g. the United Kingdom and Spain), there is a separate voice line. The download speeds vary depending on the quality of the cable infrastructure, but are typically between 2 and 70 times those of a dial-up connection.[37] Typical consumer offerings range from 150 Kbps up to about 3 Mbps, although UPC chello, the leading cable company in the Netherlands, announced in 2003 the capability to offer a 10 Mbps service over some existing infrastructure. For consumers, the data services available are essentially identical to those of DSL, but with the potential advantage that they can be bundled with broadcast as well as voice services.

One potential weakness with cable is that unlike with the copper local loop, users share bandwidth with their neighbours. At peak periods, this sharing may result in a reduced access speeds for some users. However, as demand for bandwidth increases, this can be met by splitting fibre nodes (i.e. the connection from the cable head-end), which has the effect of reducing the number of customers sharing limited bandwidth on coaxial cable. This is a relatively straightforward and cost-effective method of upgrading two-way lines in response to rising demand.

Unlike copper loops, cable roll-out varies widely across European countries, so many potential consumers do not have access to this service. Also, much of the original cable infrastructure in Europe was laid for television and has only a one-way link to the home. Cable needs to be upgraded to two-way links to provide internet access. This requires a change in network topology that is not required for DSL. During the late 1990s, many cable companies pursued aggressive roll-out and upgrade strategies but in recent years this has been checked by financial difficulties. Where cable roll-out and upgrades are extensive – for example in Belgium and the Netherlands, cable companies have generally been very successful in winning broadband market share in competition with DSL, and they are likely to remain so for the foreseeable future. In this regard, they have been helped by economies of scale resulting from the worldwide deployment of the ITU-sponsored DOCSIS standards.

2.3.3 Fibre to the home (FTTH)

FTTH is deployed in a similar way to standard cable, but uses optical fibre all the way to the home rather than only as far as the nearest cable distribution node. FTTH permits exceptionally high bandwidth, typically between 10 Mbps and 10 Gbps, depending on whether the fibre connects all the way to the user or to the curb. This performance is far superior to cable or DSL, notwithstanding the fact that – like cable – shared use of lines can reduce speed for users. It can carry voice, data and video services simultaneously.

The main obstacle to the deployment of fibre is the high cost of some components and of installing new cable, which may require trenching work. However, in many cases, it may be possible to use existing cable ducts into buildings (procedures and regulations for duct sharing are long established and no different for broadband from narrowband). Equipment costs are falling rapidly as

[37] IDC (2003), page 10.

deployment increases (although the scale of deployment is modest compared with DSL and cable to date); however, installation costs are mainly due to labour and so cannot be expected to fall significantly. Therefore the economics of fibre deployment can be expected to remain driven by the question of whether returns are sufficient to justify deployment. At present, the much higher bandwidth provided by fibre is not required for most existing applications, although this could change quickly if demand for new bandwidth-hungry services takes off.[38]

Some innovative entrants, notably in Sweden and Italy, are rolling out fibre in selected urban areas, and are winning significant customer bases. There have also been smaller scale FTTH deployments in other countries, notably Denmark and Austria (see section 3.2.1 for a list of examples). Nevertheless, in the immediate future, new fibre build is likely to be focused primarily on new building developments, where there is little reason to deploy copper loops or coaxial cable as the costs of deploying fibre are similar.

2.3.4 Fixed wireless access (FWA)

Fixed wireless access systems employ a point-to-multipoint radio wave link between a base station and multiple antennae. In most circumstances, a line of sight connection is required between the antennae and base station. FWA serves as a wireless replacement for copper local loops or cable drops. It can be used for both voice and data, with transmission speeds in excess of 2 Mbps, depending on the spectrum band being used.

Wireless technology offers a number of advantages over fixed links: there is no need to lay cable into customer sites, so it is much easier to roll out competing infrastructure; customer installation is relatively straightforward; and equipment can be moved and re-used. Therefore, the marginal cost of joining new customers to a network is relatively small. However, the requirement for line-of-sight path means that typically the signal from a base station will only reach about 40% of the people in a given area, potentially necessitating the need for additional base stations.[39] Transmissions are also vulnerable to signal disruption owing to heavy rain or wet foliage. At present, high equipment costs has made FWA largely uneconomic where there is existing copper or cable loop infrastructure. Two notable exceptions are in Mexico City and Hong Kong, where local operators have captured significant market shares in data traffic.

FWA has been heralded as a potential mass-market alternative to cable and DSL. The idea of 'broadband in a box', with consumers able to buy terminating

[38]Demand for services requiring high bandwidth and demand for bandwidth to support such services are clearly interlinked. For example, demand for streaming content has increased with greater broadband take-up and is conceivably a driver of take-up.

[39]Strategy Analytics (2003).

equipment off-the-shelf that they then can plug straight into their PCs, remains a potentially attractive proposition. AT&T experimented with this under the name ‘Project Angel’, but the project has apparently been shelved following the sale of the company’s cable units to Comcast. The high cost of equipment (relative to DSL or cable modems and termination equipment) appears to be the key factor preventing operators from penetrating consumer markets at present.

Existing FWA operators in Europe are focused largely on the business data market, usually in second-tier towns and cities with less developed fibre infrastructures. FWA technology has also been flagged as a way of providing broadband to rural communities where the local loop is too long to deploy DSL, but this depends on there being sufficient demand to justify the construction of base stations.

2.3.5 Satellite

Satellites can act as a bridge between users’ PCs or TVs and the carrier’s point-of-presence (POP) on the fixed internet backbone. They can be employed almost anywhere, and thus are particularly suitable for serving rural areas which cable and DSL cannot reach. Most existing services utilise existing TV satellite receiving dishes combined with digital receivers. However these typically offer only downstream transmission, at speeds of 300 Kbps to 2 Mbps. Upstream connection is completed via a dial-up connection over the phone line. A number of companies in Europe and the United States have begun introducing two-way broadband satellite services. However, take-up has thus far been limited owing to expensive equipment and installation, and problems with capacity and scalability.[40] Certain applications may be frustrated by limited upload speeds and latency.

Two-way satellite offers a potential universal solution to broadband access. However, unless costs can be reduced significantly, it is unlikely to be competitive in urban areas where other technologies are already in place. It has much greater potential in rural areas; reflecting this, many existing service providers, such as BT, Deutsche Telekom, Telefonica and Tiscali have deployed satellite as a complement to their DSL services. All these companies currently price satellite access at levels significantly above DSL services (see section 1.1.1).

2.3.6 Electric power lines

Power line communications (PLC) technology makes use of existing electricity distribution lines to transmit data signals. Users connect their PCs to the electricity network using a protocol translator, which is typically co-located with their electricity meter although some systems utilise buildings’ internal

[40] Strategy Analytics (2003).

networks. The signal then runs to the local electricity substation where a data concentrator is used to connect it to the communications backbone.

The system offers two main advantages relative to other broadband delivery platforms:

- □ The ubiquity of powerlines means this is a potential universal solution.
- □ It is potentially fast, with theoretical speeds of up to 45 Mbps.[41] Actual systems deployed to date run at about 1 Mbps.

Whether or not this technology can be made to work effectively on a commercial basis remains uncertain. There are a number of significant technical obstacles to carrying data signals over powerlines, such as the risk of radiated energy interfering with radio signals and the swamping of data signals by switching transients (e.g. owing to generators going on and off line). Furthermore, critics argue that since telephone cables are designed to carry far higher frequencies than 50 Hz power cables, data application performance over powerline is doomed to be inferior.[42] The absence of a common position on powerline standards amongst EU member states may also inhibit the development of this technology.

Trials of powerline systems are on-going in both Europe and the United States. For example, in Spain, the three main electricity operators have been carrying out tests and there are now 3,000 users in Extremadura region.[43] Meanwhile, Scottish Hydro-Electric launched trial services in 2003 in three small towns: Crieff, Campbeltown, and Stonehaven.[44] However, Europe's largest commercial trial, involving RWE in Germany, was abandoned.[45] The extent to which these trials have made progress in resolving technical obstacles is unclear. The FCC in 2003 launched an inquiry into broadband over powerlines as part of its ongoing efforts "to encourage multiple platforms for broadband".[46]

If the technical obstacles to implementation can be resolved, then powerlines could play mass-market role. In a 2003 report, IDC commented that it would be "*interesting to see what would happen if a major European provider or equipment manufacturer really began to push the solution.*"[47] However, the focus of trials on rural areas (e.g. Extremadura) which typically lack DSL or cable coverage suggests that the immediate focus is the development of powerlines is as a niche technology for deploying broadband in rural areas.

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[41] Strategy Analytics (2003).

[42] Cochrane (2003), Silicon.com.

[43] ETNO office notes (2003).

[44] see www.hydro.co.uk/broadband/.

[45] IDC (2003), page 14.

[46] FCC (April 2003).

[47] IDC (2003), page 14.

2.3.7 Point-to-point laser (PPL) / Free space optics (FSO)

This system is comparable to FWA but uses lasers rather than radio spectrum to transmit signals from the customer's premises to a backbone network. The potential bandwidth that can be provided is very large and – as users only require a transceiver mounted against a window – deployment costs are potentially small as the costs of running in cable or fibre (e.g. trenching) would be avoided. However, the technology is still in its infancy. There are potential problems related to line of sight requirements and distortions owing to atmospheric conditions. This may require some form of mesh network architecture for deployment, so that each user has a number of redundant links. In this case, there may be little need for other backhaul infrastructure (apart from to interconnect with other public networks) as the capacity of point-to-point links would be so great. Like FWA, its primary use is most likely to be for SMEs in suburban areas as a cost-effective alternative to running in fibre.

2.3.8 Wireless LANs / WiFi

A further wireless technology which may serve as a substitute to fixed broadband access are wireless local access networks (WLANs). Like FWA, WLANs use radio spectrum to transmit data. They can be used to link communications equipment (usually computers) together for private networking or to provide a public access network. Currently, the dominant standard, operated by the WiFi (Wireless Fidelity) Alliance, is IEEE 802.11b. This system operates at low power outputs, enabling broadband data transfer rates to mobile users of up to 11 Mbps over a distance of 50 metres or so (which means it is possible to have uncoordinated and unlicensed sharing of the spectrum band by many users without the risk of extensive interference problems). By the use of directional antennae, it is possible to link fixed points over much large distances using standard 802.11b equipment. Products using a new standard, IEEE 802.11g, which is capable of speeds up to 54 Mbps, are already available and expected to become widely used in 2003. These various versions of the 802.11 standard allow nomadic users, but do not incorporate any cell structure or handover between cells; therefore, they do not provide full mobility as with a mobile network.

WLANs may act as an adjunct to fixed data networks and data connections over existing mobile networks, enabling users to access both the internet and private networks at high speed. However, WLANs are also being used to provide a service that substitutes entirely for fixed broadband. Not only are WLANs being used to provide hotspot coverage and private networking, but also to deploy broad coverage public access networks. These two modes of deployment are rather different.

In the case of hotspot provision, WLANs are typically used to extend a fixed broadband connection and share the available bandwidth amongst a number of users. In this case, a fixed broadband connection is required to deploy the service and so WLAN access may not be a true independent competitor to fixed broadband. Transmission speeds are only as good as the fixed link used to provide connectivity to the Internet. If this is an ADSL link (as might be used in a typical café-based hotspot), then actual speeds will be limited by the fixed broadband connection, rather than the radio connection.

From 2002, there has been significant roll-out of WLANs in Europe and the United States, as a wireless solution for connecting computers in homes, offices and universities, and by commercial interests creating hotspots:

- In June 2003, Gartner reported that some 19.5 million units of WLAN equipment were shipped worldwide in 2002, up 120% from the previous year.[48]
- According to the CNET News.com, WiFi "*has taken off as a cheap and effective way to share resources on a network, such as a broadband connection, and it has quickly spawned a commercial hot-spot service industry aimed at delivering bandwidth in high-use areas including hotels, airports and truck stops*"[49]. For example, T-Mobile operated over 2,400 active hotspots in the United States as of July 2003, in locations such as Starbucks cafés, Borders bookstores, and airports.[50]
- In total, there were approximately 4,200 active hotspots in the United States at the end of 2002, and IDC expects wireless providers to add more than 55,000 new hot spots in the United States by 2008.[51] IDC also projects that there will be over 32,000 hotspots in Western Europe by 2007.[52]
- A June 2003 report by Allied Business Intelligence estimated that the market for WLAN-enabled notebook users could reach 58 million users worldwide by 2008[53]. However, other forecasters are more sanguine: for example, Forrester projects 7.7 million regular users in Europe by 2008, about 15% of lap top owners and 20% of WiFi-enabled PDA owners.[54]
- The largest European deployment of WLANs to date is at the University of Twente in the Netherlands, with 650 access points covering 140 hectares to serve the 8,500 students and staff.[55]
- Paris is now close to offering widespread WiFi coverage, as Cisco plans to install antennae at the majority of Paris' many Metro stations.[56]

WLANs can also be used to provide broad coverage public access, providing backhaul networking wirelessly through the use of directional antennae. In this

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[48]Total Telecom (June 2003a).

[49]CNET News.com (July 2003a).

[50]T-Mobile Press Release (May 2003).

[51]T-Mobile Press Release (May 2003).

[52]Cellular Online (June 2003).

[53]Total Telecom (June 2003b).

[54]Forrester (June 2003b).

[55]Total Telecom (June 2003c).

[56]The Inquirer (May 2003).

case, wireless base stations may be connected wirelessly to other wireless base stations. The overall network would be interconnected with the Internet at a number of fixed points using commercial backhaul. In this case the wireless service is *not* reliant on any fixed broadband service to operate.

A number of commercial broad coverage services are already underway. For example, Irish Broadband offers WiFi-based broadband in Dublin. Following "high demand for its products", it plans to roll out service in other Irish cities, using 2.4 GHz base stations interconnected using 5.7 GHz wireless links.[57]

2.3.9 Third Generation (3G) mobile

Mobile communications offer an alternative medium to fixed wireline and wireless infrastructure for accessing the internet and sending and receiving data transmissions. Existing 2G phones using GPRS can be used to transmit data at rates equivalent to a standard analogue dial-up connection, although they can provide an always-on connection. However 3G systems, which are currently being deployed, are capable of much faster transmission rates (albeit to a limited number of users in any single cell area). The European 3G Universal Mobile Telecommunications Service (UMTS) standard provides for rates of 2 Mbps for stationary phones, 344 Kbps for a person walking and 144 Kbps in a moving vehicle, which are comparable with many existing DSL and cable broadband offerings. However, realistic rates at launch for 3G networks may be somewhat less than this.

A key advantage of 3G over other broadband access devices is, by definition, its mobility. Users are not tied to a specific location, and can send and receive large data files anywhere where there is coverage. Although the physical size of handsets imposes limits on users' visual experience of some data applications, this can be addressed by linking handsets to portable computers. The development of 2.5G and 3G technologies is also driving innovation in access devices. For example many mobile operators now market 'data cards', mobile access devices designed specifically for data transmission that can be plugged straight into laptops.

As a potential competitor to DSL and cable, the ubiquity of mobile phones is important. As of May 1 2003, Mobile Communications estimates that there are 307.7 million mobile subscribers in Western Europe, a penetration rate of 78.7%.[58] Although nearly all these subscribers currently use 2G, most European mobile operators are currently rolling out 3G networks. Once 3G networks are in place, the marginal costs of providing data transmissions are small. Therefore, 3G operators will have strong incentives to win customers and maximise traffic by offering attractive services.

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[57] ZDNet UK (October 2003).

[58] Total Telecom (June 2003d).

For some users, 3G may be a useful complement to fixed broadband services, and the experience of fixed broadband may boost demand for 3G and vice versa. Using both platforms may increase consumers' understanding of what benefits data services offer and so boost demand in general. As experience of data services grows, however, these services may increasingly be substitutes, either at the level of usage decisions, or even at the point of deciding to subscribe at all.

Here, an analogy can be drawn with voice, where there is substantial empirical data of substitution with mobile telephony at the levels of individual calls and access choices, and evidence that this substitution has increased as mobile call charges have declined and mobile phone ownership become ubiquitous.[59] This form of substitution can occur even if prices of fixed and mobile services are rather dissimilar. By analogy, once 3G technology is mainstream, there may be a strong price incentive for consumers with modest broadband demands to use their mobile devices rather than subscribe to an infrequently used fixed service, especially as it becomes increasingly easy to interconnect mobiles and PCs without specialist knowledge. The extent of substitution will be primarily determined by the trade-off between the cost-effectiveness for users of using 3G for additional data communications versus signing up to an entire fixed broadband access package.

The extent of substitution between fixed and wireless data technologies depends on the nature of service and customers' needs. Mobile connections have some vulnerability to link disruption and cell capacity limits, although similar problems also affect fixed broadband technologies to differing extents. More significantly, proposed data rates for initial implementation of 3G are substantially below those for most fixed access technologies, making it unsuitable for some high bandwidth applications. However, mobile operators are already offering bundled services using WiFi hotspots and their future data services offers may be based on variety of underlying technologies, including GPRS, EDGE, 3G and WiFi. Therefore, for many users, mobile solutions will offer sufficient bandwidth in a sufficient variety of locations (with wide coverage at lower bandwidths) to be an effective substitute for fixed services. For fixed and mobile services to compete, it is not necessary for them to have very similar characteristics or for all customers to consider them substitutes; what is required is that a sufficient number of customers (which could be a minority of all customers) find the services substitutable.

[59]For example, Horvath and Maldoom (2002) analysed survey data on over 7,000 British telephone users in order to investigate the link between mobile phone ownership and fixed telephone usage. Controlling for underlying taste differences between fixed and mobile users, they found strong evidence of fixed-mobile substitution at both the call and access levels.

2.3.10 'New mobile' technologies

As a substitute for fixed broadband access systems, WLAN and 3G technologies each have drawbacks: WLANs have high speed but limited mobility; and 3G provides wide coverage but is slower than most fixed broadband (at least as it is likely to be initially deployed). However, future developments of these technologies promise to combine the mobility and range of mobile with the transmission speeds of WiFi. Assuming these can be developed as commercial services, such technologies would appear to have the potential to satisfy the broadband access requirements of most users and provide full mobility at the same time.

The future evolution of mobile data services is uncertain, owing to the many different potential technology paths; in particular, it is possible that a number of competing standards could emerge. Mobile operators (and other providers) may offer data services over a mixture of different technologies, reflecting the comparative advantages of different technologies in different situations and the impact of legacy systems. These different technologies may eventually be knitted together to provide seamless service.

A popular description for any mobile technology that offers superior data handling capabilities to those currently available is '4G', though we do not consider this a meaningful term. Technologies identified under this banner may be better described as extensions of existing 3G and WiFi technology. For example, the latest W-CDMA standard (a 3G technology) can potentially offer speeds of up to 10.8 Mbps. We use the term 'new mobile' to describe such technologies.

There are already products coming to market aimed at business and high-end residential users which promise wide-area data access at broadband speeds, using a development of existing WLAN standards to include cell structures and cell handovers. Companies developing technology under this banner include ArrayComm, Broadstorm, Flarion Technologies, IPWireless, and Navini, and trial deployments are already underway in parts of Canada, Germany, Italy, the Netherlands, New Zealand, South Korea, and the United States.[60] Both Flarion and ArrayComm, for example, are developing end-to-end IP networks, with full on-demand capability:

- Flarion is in talks with a number of mobile carriers, including Nextel in the United States, about deploying its Orthogonal Frequency Division Multiplexing technology on top of current networks.[61]
- ArrayComm is engaged in the live deployment of its iBurst technology in Sydney, Australia, under the marketing banner of "personal broadband" for

[60] The Economist (May 2003).

[61] ComputerWeekly.com (June 2003).

consumers and business.[62] Promising initial speeds of 1 Mbps, its plans to roll out its network across urban Australia, using 5MHz of 3G spectrum purchased in a 2001 auction. Initial pricing is highly competitive: as of June 2003, ArrayComm was projecting a price of 35 Australian dollars per month (20 euros), which compares favourably to other forms of broadband access.

Notably, Arraycomm's technology is suitable for deployment over unpaired frequency allocations (TDD) in and around the bands 1800-2100 MHz, which are owned by mobile operators across the EU but at present not being used.[63] These unpaired blocks have, until recently, been seen as having little value and were envisaged for various in-building and unlicensed deployments of 3G networks. However, it is now clear that these blocks have great potential to be used for data traffic. Moves towards technologically neutral licensing of spectrum are likely to mean that new data services can be deployed within existing spectrum assignments.

For consumers and business users who value both home and remote access to broadband, 'new mobile' technologies could provide a one-stop solution. Ultimately, whether these technologies can attract customers away from fixed broadband access will depend on whether they can be shown to work effectively; whether investors can be found to finance the costs of deploying networks; and whether the end-user price is competitive. It is too early in the development of these technologies to draw firm conclusions. Nevertheless, mobile operators are an obvious source of investment in these services notwithstanding the problems they have experienced with the cost of rolling out 3G networks: they have existing customer bases to market these services to; existing billing systems; and can potentially develop integrated offers with other mobile services.

[62] http://www.arraycomm.com.

[63] All 3G operators in Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and Sweden, plus 3 of 6 operators in Austria, 5 of 6 in Germany and 4 of 5 in the United Kingdom were awarded TDD spectrum.

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