Economic Development Committee **EDC 08-02(p4)**

Date: **8 May 2002**
Time: **14.00 - 17.30**
Venue: **Committee Room 1, National Assembly, Cardiff Bay**
Title **Broadband: Opportunities and Barriers**

1. Introduction

The information revolution is comparable in importance to the agricultural revolution and the industrial revolution. It is generally accepted that full use of information technology is a prerequisite for success in the new, knowledge-based industries and there are stark differences between success and failure. Knowledge-based industries will move to areas where there is already broadband infrastructure, and they will create the extra demand that justifies further investment. Areas with inadequate IT infrastructure will not attract these industries, demand will remain low, and the operators will be reluctant to invest.

This choice is well illustrated throughout rural Wales. Because knowledge-based industries can locate anywhere in the world where there is adequate broadband connectivity they tend to concentrate in those areas where the quality of life is highest. There are many attractive areas of Wales that with broadband infrastructure would enjoy an unique advantage; without the infrastructure they will be ruled out entirely. It is therefore crucial to our economic strategy that Wales does not fall seriously behind in this field.

However, we are chasing a rapidly moving target. The development of information technology in the past 40 years has been extraordinary. Standard desk-top computers process data at a cycle frequency of over 1 GHz, with memory capacity of several Gigabytes at a price that continues to fall rapidly; major data centres multiply these figures by a 1000. It is now possible to handle unprecedented quantities of data, and so the rate of data communication is crucial. A high data rate requires a correspondingly high frequency bandwidth in the channel of communication: hence the importance of ‘broadband’ telecommunications.

2. What is "broadband"?

There are several definitions of ‘*broadband*’. Ideally a broadband link should be sufficient to transmit video information of acceptable quality in both directions. For a standard analogue transmission this would require a bandwidth of several Megabits per second (Mbps), but using "compression" (see below) a bandwidth of 256 kilobits per second (kbps) is just about adequate in most cases.

Nevertheless some operators use the term ‘broadband’ when the downstream link ***to*** the subscriber is 256 kbps, while the upstream link ***from*** the subscriber may be as low as 64 kbps. Such a connection is described as ‘asymmetric’ - as in ADSL, an Asymmetric Digital Subscriber Line. In discussing the situation in Wales it is convenient to define the lowest communication rate that can be described as broadband as the version of ADSL available for residential services i.e.512 kbps downstream and at least 64 kbps upstream. In future, however, we will need true broadband such as SDSL (Symmetric DSL: ~2 Mbps downstream and upstream) or VDSL (Very-high-data-rate DSL: ~10 Mbps downstream and upstream).

3. Why broadband?

Most information is carried by waves – such as sound waves or electromagnetic waves. A wave is characterised by its *frequency* – the number of cycles of the wave passing a single point per second. FM Radio 4 on vhf (very-high-frequency) is transmitted at a frequency of about 94 million cycles per second or 94 MegaHertz (MHz). One of the proposed frequencies for wireless broadband transmissions in Wales is 28 billion cycles per second or 28 GigaHertz (GHz). In comparison, yellow light has a frequency of 500 trillion cycles per second or 500 TeraHertz (THz).

A ‘pure’ wave at a single frequency cannot carry information. However, if two waves of slightly different frequencies are added together they combine in or out of phase so that the combined wave ‘beats’ at a frequency equal to the difference between the frequencies of the two component waves and this modulation of amplitude conveys information. If more frequencies are added over a wider frequency range more complicated and faster modulations are possible, and the information carried is correspondingly greater.

It can be shown mathematically that the maximum rate of transmitting information along a channel is equal to twice the total range of frequencies or *'bandwidth'* passing through the channel. Thus a bandwidth of 100 Hz can transmit 200 separate and independent measurements a second whereas a bandwidth of 2 MHz can transmit 4 million measurements a second.

An analogue television signal, scanning 625 lines 25 times a second, transmits about 13 million independent measurements a second (1 per pixel per scan) and hence requires a bandwidth of about 7 MHz. The uhf (ultra-high-frequency) band, with a total bandwidth of 2700 MHz, can carry a significant number of high-fidelity television channels, as well as providing bandwidth for the mobile phone networks. Normal visible light has a bandwidth of about 300 THz – about 100,000 times greater than the whole of the uhf band. ***That is why, in theory, light is capable of carrying far more information than the whole of the radio bands put together: hence the importance of optro-electonics.*** For example, using ‘*Dense Wave Division Multiplexing*’, a total of over 1 GHz bandwidth, divided into separate channels, can be carried along a single optic fibre.

4. Bandwidth Compression

Frequency bandwidth is a strictly limited natural resource, and bandwidth '*compression*' describes various techniques to reduce the information content of a signal, and hence reduce the bandwidth of frequencies required to send the signal. The most familiar case of bandwidth compression is the way digital television transmits many separate programmes over the same uhf bandwidth previously required for a single analogue channel.

As described above, a normal analogue television transmission provides separate and independent information on the intensity and colour of each spot (or '*pixel*') on the screen 25 times a second. As there are over 500,000 pixels on the screen this requires an information flow describing 13 million pixels a second - hence the need for a wide uhf bandwidth to transmit colour television. If high-definition television is introduced the necessary bandwidth will increase still further.

However, adjacent pixels on the screen often have the same intensity and colour. For example, when a film is shot against a room wall that is uniformly lit and painted in a single colour a very modest amount of information may be needed to define the area covered, the intensity of the illumination and the colour used. This information can then be transmitted instead of the individual intensities and colours of, say, 100,000 pixels. Even more important is the fact that the information may not change very quickly so only the *changes* in information between one scan to the next need be transmitted.

As a result of these techniques bandwidth compression by factors of 25 or more can be used for video transmission, so that a channel bandwidth of 256 kHz can be used to transmit a compressed version of the video information that would normally require 7 MHz.

The result is a picture that is usually adequate but not perfect. It is certainly adequate for filming a speaker in a plenary sessions of the National Assembly from a fixed camera position: in this case there is a constant background to the picture and few rapid movement. (The video engineer and the saloon-bar cynic would agree that very little was happening and the information flow was tiny). In contrast there is limited potential for compressing the video transmission of a very fast-moving sporting event with rapid camera scans.

One feature of bandwidth compression is that it requires the information to be processed, and hence it is coded in a digital form.

5. How much bandwidth is needed?

How long is a piece of string? There are some subscribers who will always have a legitimate requirement for exceptionally broad bandwidth. The Grid (the latest version of the Joint Academic Network or JANET, now available in Cardiff) has over 3 GHz bandwidth. A full

Virtual-Reality link for joint 3-dimensional work at a distance ideally requires a 1 GHz link, though if the environment studied is only slowly changing bandwidth compression can reduce this to 100 MHz or less. My own experiments need about 30 MHz.

However, for the vast majority of subscribers a high-resolution video image, matching the angular and time resolution of the human eye, sets a natural standard for communication. ADSL can just about meet this target and a symmetric VDSL will comfortably meet the needs of most SMEs and domestic subscribers for some years to come.

Therefore our immediate aim must be to make ADSL - or its equivalent - available to 90% of the population of Wales by 2005, with the prospect of upgrading to VDSL by 2010.

6. How can broadband be transmitted?

To convey information from sender to receiver the signal is either '*channelled*' or '*broadcast*'. When a signal is 'channelled' it travels from the source to a chosen destination along a defined path without spreading in all directions. Normal telephone lines provide the best known example. The channel may be twisted-pair copper wires, a coaxial cable or an optic fibre. The word 'broadcast' (taken from the Parable of the Sower, Matthew 13, 3-9) describes transmission from an antenna in a wide range of directions. Thus radio and television signals are broadcast from a network of terrestrial stations, or from a geo-stationary satellite trapped in a stable orbit 36,000 km above the equator.

i. Channelling via Land Line.

At present the main way of providing a broadband service to subscribers is via a fixed land-line, normally a copper pair, a coaxial cable or an optic fibre.

The different ways of providing broadband connectivity in the UK, the EU and all OECD countries is summarised in table 1.

Table 1: Broadband Connectivity June 2001

	DSL	Cable Modems	Fibre	Broadband/100 inhabitants
UK	80,772 (49%)	83,750 (51%)	0 (0%)	0.28
EU	1,913,157 (58%)	1,152,736 (35%)	213,500 (7%)	0.82
OECD	10,643,752 (48%)	11,138,333 (51%)	214,050 (1%)	1.96

The main advantage of sending a signal along a land-line is that the signal is confined to the line and not broadcast into free air so there is no problem of '*frequency contention*' when two signals, transmitted at the same frequency, interfere with each other.

Normal telephone signals are distributed via a copper pair. With a suitable modem this is adequate for carrying signals with a bandwidth of up to 56 kbps. However, when a normal telephone wire is used for carrying a broadband digital signal, as in ADSL, it is susceptible to noise degradation which increases as the length of the line increases.

(Here there is a significant difference between analogue and digital signals. When an analogue signal is corrupted by increasing levels of interference or '*noise*', the quality of the signal deteriorates steadily. In contrast, in a digital signal each bit of information is either 0 or 1. Provided the level of noise is small enough to preclude the misreading of 0 as 1, or vice versa, the effect of noise is automatically corrected and the signal received is still identical to the signal transmitted. If checking codes are added the signal can even be corrected when a single bit is read incorrectly. However, if the noise level increases to the extent that the correction mechanisms break down, then the signal is totally corrupted. (This explains why the picture received by digital televisions is either of very high quality or breaks up completely).

As a result of noise on the telephone line, residential ADSL is only available up to a distance of 3.5 km from the exchange, and for the UK as a whole this covers just over 70% of phone lines. BT have recently introduced R-ADSL (Rate-adaptive Asymmetric DSL) which in theory maintains the downstream bandwidth at 512 kbps but reduces the upstream bandwidth, in steps, to a minimum of 64 kbps. With this modification R-ASDL can be delivered along copper pairs up to a maximum distance of 5.5 km. For the UK this covers 95% of phone lines but for Wales the proportion is certainly lower.

A recent OECD report estimates that in June 2001 48% of subscribers to broadband Internet access in OECD countries (and 49% of subscribers in the UK) used DSL via phone lines. In the future, however, when the inevitable move to VDSL occurs, the distance limitation on normal phone lines will become even more restrictive and an alternative may be essential.

Until 2001 there was a second limitation to broadband via phone lines in the UK, regulative rather than technical. In the 1990s BT were prevented by competition rules from using their phone lines to send television signals to subscribers; had they been allowed to do so then broadband connectivity may have become available throughout Wales several years ago.

The main competitor for phone line DSL is a connection via co-axial cable, and in June 2001 51% of Internet connections in OECD countries – and in the UK - was via cable. A co-axial cable has the advantage that it is protected from external noise and hence can offer a wider bandwidth and does not suffer the same distance limitations. Moreover, in the 1990s the regulations in the UK allowed the supplier, (now NTL), to offer telephone, internet access and television in a single package.

However, whereas almost every office and residence in Wales is already connected to the telephone system, a cable network has to be installed anew. This is a major task ("digging up every street"); so far in Wales only the largest conurbations in the South have been covered and it is unlikely that small communities in sparsely-populated rural areas will ever be connected in this way.

Finally, optic fibre provides what is technically the best way of delivering a broadband signal to a specific destination, using light signals that offer, in theory, a frequency bandwidth many million times greater than the competition. In practise, as with coaxial cable, a new network has to be physically installed and this may also involve digging up streets to install appropriate ducts. (It should be noted, however, that any ducts already provided for a cable network will also be available for a fibre network).

In addition, the equipment necessary to receive or transmit the optical signal is still relatively expensive and so far only Sweden (50%), Iceland (14%) and Italy (6%) provide a significant proportion of broadband connections directly to the home or office via optic fibre. In the UK it is possible to use a fibre leased-line to any location but the costs are very high.

However, optic fibre is increasingly used to provide the ‘backbone’ of a broadband network, even if the final link from exchange to subscriber is via copper pairs or cable. Thus all but a few of the telephone exchanges in Wales are linked by fibre, but only a limited number so far have the equipment to offer ADSL via normal phone lines to subscribers within 3.5 km. These few, however, include the 10 towns in rural Wales served by the Llwybr 6 project

i. Broadcasting

An alternative way to provide broadband connectivity is by broadcasting the signal. This is an ideal method when the information flow is in one direction only, and the same signal is intended for a large number of subscribers in the same geographical area. If however it is required to broadcast a different signal to each subscriber, and receive a different response from each, then it is necessary to choose a different frequency in each case to avoid ‘cross talk’. Once a frequency has been used by a transmitter, the same frequency cannot be used again within a certain distance or else the two signals will interfere with each other. Unfortunately, only a fixed bandwidth is available in any frequency band and the consequent ‘*frequency contention*’ restricts the number of different signals that can be transmitted simultaneously.

Frequency contention is a serious problem when there are many subscribers in a single area e. g. 100,000 subscribers in an urban area. It is less of a problem in a sparsely populated rural area.

The problems of frequency contention can be mitigated in several ways. Using a more elaborate antenna system the transmitted signal can be concentrated into a narrow beam in the exact direction required rather than distributed over a wide angle. At the same time the strength of the signal can be reduced to the minimum needed to reach the actual destination. Similar techniques have been used to reduce contention for mobile-phone frequencies that operate in the upper half of the uhf band, but a single mobile phone requires a much smaller bandwidth than a video signal.

A simpler way to reduce frequency contention is to move to a higher frequency where far more bandwidth is available. It is suggested that broadband fixed wireless communication (BFWC) in Wales might be centred on either 28 GHz or 40 GHz.

Unfortunately, at such high frequencies new problems arise. First, as the frequency increases the ability of an electromagnetic wave to ‘bend around a corner’ is reduced and at 28 GHz or higher the signal effectively travels in straight lines so that the receiver must be in line-of-sight of the transmitter. This is a very serious problem in a hilly country where it will be necessary to install a dense network of transmitting masts.

At the same time, the hills do reduce the problem of frequency contention. A hill-top mast could direct its beam into a narrow valley and serve a small number of subscribers without affecting any other community, but as soon as the number of subscribers reached the bandwidth limit this technology would no longer be adequate.

The second problem with broadband at such high frequencies is that the signals are badly affected when the transmission path passes through heavy rain, or even when there are large variations in atmospheric pressure. It is therefore impossible to guarantee 100% reliability with a wireless link.

Nevertheless, in a flat and sparsely populated country (e.g. Finland), wireless transmission of broadband signals may be a cost-effective solution for serving small, remote communities.

One way of overcoming the problem of line-of-sight communication, and reducing the effect of scattering by rain, is to use satellite broadcasts. A suitably located geostationary satellite is within line-of-sight of most of Wales and as the signal passes through the atmosphere at an elevation of about 30 degrees the path-length through heavy rain is shorter than for a terrestrial transmission close to the horizontal. However, for broadcasts from satellites frequency contention is a serious limitation. Moreover, costs are higher. Satellite broadband is therefore likely to be a solution for a small number of customers with a heavy demand for broadband links where the extra cost is not a serious factor e.g. a medium or large enterprise located in a rural area where broadband DSL is not available.

Another technology that is in its infancy is the use of infra-red radiation to carry the broadband signal. In this case a narrow beam can be formed with a small device. However, it is also a strictly line-of-sight transmission and requires small repeater devices every 3 km or so. I understand that a pilot scheme is being deployed in Hereford and if it is successful it will be worth studying.

To summarise: there is no doubt that in the short term wireless communication or satellite could be cost-effective ways to provide broadband to a small number of subscribers. These technologies are unlikely to meet the medium-term aim of providing broadband to a significant proportion of the population in a hilly country like Wales with high rainfall where the majority live in urban settlements.

7. The Present Position in the UK and Wales

There can be no doubt that at present the UK is rapidly falling behind the rest of the world in broadband connectivity, and Wales is falling behind the rest of the UK.

A recent report by the OECD Working Party on Telecommunications and Information Services Policies entitled "The Development of Broadband Access in OECD Countries" lists the total broadband penetration per 100 inhabitants in June 2001 (Table 2).

South Korea has the most advanced broadband network, with 13.91 connections per 100 population, and Canada is second with 6.22.

In Europe, Sweden heads the list with the most advanced broadband network - and the most ambitious plans. Already in June 2001 there were 4.52 broadband subscribers per 100 population and by 2004 the Swedish government plans to provide broadband connectivity to 98% of all towns and villages.

At the cutting edge of this programme Sweden has the fastest growing fibre-optic network in the world. This network, provided by Bredbandsbolaget, offers a symmetric capability at a rate of 10 Mbps, and within 3 years of its foundation it had connected 199,000 subscribers – 50% of the total number of broadband subscribers or 2.25 connections per 100 population.

In contrast the UK lies in 22nd place in the OECD list with only 0.28 broadband connections per 100 inhabitants– well below Portugal, Spain and Italy. This figure can be compared with the average of 0.82 for the EU and 1.96 for the OECD as a whole.

Table 2: Total Broadband Penetration in June 2001

Country	**Total Broadband Penetration / 100 inhabitants**	**Country**	**Total Broadband Penetration / 100 inhabitants**
Korea	13.91	France	0.59
Canada	6.22	Australia	0.59

Sweden	4.52
USA	3.24
Netherlands	2.74
Austria	2.36
Denmark	2.33
Belgium	2.27
Iceland	1.99
Luxembourg	1.60
Germany	1.03
Japan	0.94
Switzerland	0.90
Finland	0.73
Portugal	0.57
Norway	0.52
Spain	0.47
New Zealand	0.45
Italy	0.44
UK	0.28
Czech Rep.	0.11
Hungary	0.09
Poland	0.07
Mexico	0.02
Ireland	0.01
Greece	0.00

Alas, Wales lies in bottom position among the 12 regions of the UK. Thus the DTI in 2000 allocated an index of connectivity for each of the regions of the UK, based on 11 parameters including use of e-mail, Internet access, Web sites, LANs and WANs. Wales came last in seven of these measures, and in the bottom three for all 11. The overall results are listed in Table 3, taken from the WDA Report ‘Ubiquitous Broadband Infrastructure for Wales, July 2001.

The prospects for the immediate future are not encouraging. According to the predicted proportion of the population "passed by different Broadband access technologies" in 2003 (Table 4), Wales will remain at the bottom of the list unless there is a serious intervention by government.

Table 3: Connectivity Index 2000

Nation / Region	**Connectivity Index (UK=100)**
Greater London	110
South East England	105
West Midlands	104
East England	98
North West England	95
Yorkshire and Humberside	95
East Midlands	95
Scotland	95
Northern Ireland	94
North East England	93
Wales	86

Table 4: Predicted proportion of population with access to Broadband in 2003

	ADSL & Cable	**ADSL** **(not Cable)**	**Broadband Wireless**	**Nothing**
London	95%	5%	0%	0%
Northern Ireland	45%	40%	10%	5%
North-East	60%	20%	10%	10%
North-West	50%	15%	20%	15%
Yorkshire and Humberside	40%	25%	20%	15%
West Midlands	55%	10%	20%	15%
Scotland	20%	35%	25%	20%
South East	45%	30%	0%	25%
East Midlands	30%	35%	0%	35%
East England	30%	35%	0%	35%
South West	25%	30%	0%	45%
Wales	20%	35%	0%	45%

8. A Strategy for Wales

The purpose of this paper is to review the present situation in Wales, to agree on a long-term target and to consider how plans already announced by the government can help us achieve that target.

There is no doubt that the present situation throughout most of Wales is unsatisfactory and left to commercial forces alone the digital divide will widen. There is therefore widespread agreement that the public sector, supported by European structural funds, must play a major role in stimulating the demand for broadband connectivity in deprived and sparsely-populated areas.

There is also general agreement that the first step must be to provide a comprehensive public-sector network serving all local government, colleges and schools, libraries, hospitals, surgeries and industrial estates.

What is important in the longer term is that this first step should everywhere be carried out in a way that facilitates the future extension of the network to serve all SMEs and private households in the locality. To ensure that this is the case we must have a clear outline of the comprehensive system we envisage in 2005 - and in 2010.

In the first place there needs to be a full discussion on the technology that best suits Wales. This is not to say that a range of technologies may not be needed to meet niche demands, but there is a danger in adopting a ‘technologically neutral’ approach.

Microwave links might provide the most cost-effective service to a few remote communities. Satellite might answer the immediate needs of a medium-sized enterprise that does not lie near a cable service and does not have easy access to an exchange with ADSL. However, the medium that allows the most rapid availability of ADSL in every community in Wales, and the easiest subsequent transition to a symmetric VDSL, is undoubtedly optic fibre to within a short distance of the final destination.

For example, if Cymru Ar Lein provides a separate optic-fibre link to every school in Wales then in principle ADSL becomes available to subscribers living within 3-5 km of the school via normal telephone lines. By installing the appropriate equipment in a school-yard '*cabinet*' and linking this to the telephone system this potential can be rapidly exploited.

Later, when there is a need for symmetric VDSL, the maximum distance over which this will be possible in copper pairs will be less than for ADSL, but this problem can be overcome by repeater technology or by replacing the copper pair with fibre-to-the-home, as in Sweden. It will still follow an evolutionary path so that the investment made at each stage leads naturally to the next step in the plan.

It is therefore vital that this should be kept in mind when installing the links to the school to make sure there are no subsequent technical or regulatory barriers preventing the full evolution. For example, care must be taken to ensure that contracting a public-sector firm to manage the project does not infringe 'state-aid' rules. Also the restrictions on using any network associated with JANET for normal commercial subscribers must be considered.

The final question, as always, is the question of money. Various estimates have been made of the total cost of providing ADSL or its equivalent to every town and village in Wales – a very modest plan when compared with the strategy adopted in Sweden. These estimates range from £100 million to £160 million – substantial sums unless we accept that broadband connectivity is indeed a sine-qua-non for future economic prosperity. It must also be remembered that a total of £66 million, including 'match-funding', is available in Objective One, Priority Two, Measure One – the measure supporting IT infrastructure. Properly used in partnership with the telecommunication providers and supplemented by the existing budget for IT a large part of this plan is affordable.

9. Conclusion

Information Technology is a complex and rapidly changing topic. Yet it is proving central to economic development in many countries. It is therefore highly desirable that the potential of the technology should be debated openly and fully in the Economic Development Committee. This is especially urgent because of the way Wales is falling behind the rest of Europe and this gap must be eliminated.

We start with the advantage that most of the 550 telephone exchanges in Wales are already served by an optic-fibre backbone. We have the second advantage that many areas of Wales are intrinsically attractive and provided broadband connectivity is available would prove a magnet to young entrepreneurs in the knowledge economy. Finally, Wales is already strong in the opto-electronic sector and the planned development of a broadband network in Wales could help stimulate demand in this sector.

All of these are issues that vital to economic development and it is welcome that the Minister responsible for Information Technology is now a member of the Committee so that a full discussion can take place within the context of our economic strategy.

Phil Williams
May 2002