ODTR BRIEFING NOTE SERIES

Technology Developments in Telecommunications

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Foreword

A prominent feature of the infocom sector is the extent to which it is subject to rapid technological innovation and changing market conditions. Keeping pace with these developments is one of the most difficult challenges regulators face, as we strive to ensure that our regulatory approaches and methods are appropriate and timely.

At our New Issues Conference[1] and elsewhere I have emphasised the need for this Office to anticipate technological and market developments so that we can assess and prepare for regulatory changes that may be required as a consequence. Since the Conference, we have developed what we refer to as our Forward-looking Programme. This programme aims to monitor trends and developments within the global infocom sector, identify which ones may give rise to new regulatory issues, and assess priority topics. These priority topics are then assessed in more detail, particularly in terms of potential for helping develop the Irish infocom sector, bearing in mind our strong focus on "price, choice and quality" for Irish consumers.

The main products from these assessments are what we term "Briefing Notes". Although they deal with complex, technical topics, they are intended to inform readers who are broadly familiar with telecommunications, but who may not have technology backgrounds. While the principal purpose of these notes is to help me and my team develop our work programme and take decisions, we recognise that some of them may fulfil a wider role: in creating awareness, developing interest and, in appropriate cases, stimulating investment in new or evolving technologies that will help in developing Ireland's infocom sector and in achieving our "price, choice and quality" objectives.

I have therefore decided to publish this initial collection of recently-prepared Briefing Notes. In so doing, I would emphasise that these are merely short, preliminary analyses of complex and fast-developing subjects and do not address all the technical, financial and operational considerations of each topic. While I hope that some companies who are already active in or are considering entering the Irish market may be prompted to consider these technologies, they will of course have to conduct their own assessments.

[1] See www.odtr.ie document 00/80

I intend to publish further Briefing Notes from time to time on subjects of relevance to the Irish market, now or into the future. In the meantime I would welcome comments from interested parties on this first series.

Etain Doyle.
Director of Telecommunications Regulation.

Contents

1 Introduction

These five Briefing Notes on technical topics have been produced as part of the ODTR's Forward-looking Programme and following on from last year's New Issues Conference[2]. These notes are intended to raise awareness and to provide background information on the topics covered. The notes are primarily aimed at non-technical readers with some background knowledge of current telecommunications technology. However to aid lay readers, and to help put some of the notes in context, an introductory section and an annex have also been included providing a basic background in relation to current broadband access issues and technologies.

Two of the topics included in this collection consider alternative transmission methods for wireless systems; *"Optical Wireless"* and *"Ultrawideband"*. The next two notes describe delivery platforms for wireless services; *"HAPS"* and *"Broadband VSATs"*. The final topic is *"Software Defined Radio"* which represents an evolution in the way radio equipment is implemented.

Readers are also referred to the recent consultation paper on FWA *"New Opportunities in the radio communications market: Fixed Wireless Access (FWA) – Consultation Paper"*[3], which discusses recent technology developments including wireless LANS.

We welcome comments on any of the Briefing Notes and these should be sent to:

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In submitting comments, respondents are requested to reference the relevant Briefing Note from this document. Apart from expressions of interest, responses to this document

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[2] See www.odtr.ie document 00/80

[3] See www.odtr.ie document 01/43

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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2 Background to Broadband Access Issues

Despite the turmoil and realignments currently being experienced by the '*infocom*' sector, it is clear that we have already entered the "Information Age", and are well on the road to building an "Information-based Society". Even after significant consolidation, *infocom* sector companies accounted for more than fifty percent of the market capitalisation of the top fifty companies in a recent global FT 500 list. Moreover, as was pointed out recently[4], the Internet has developed to the extent that it can now be regarded as a 'general purpose technology'[5] permeating a wide range of economic and social activity. Electronic mail, web browsing and early-stage e-commerce are already commonplace in much of the developed world.

Looking forward, these early "killer applications" are likely to be joined by others such as telepresence, and new and sophisticated on-line learning and medical services. The expectation among some leading commentators is that this will probably happen sooner and on a greater scale than is widely appreciated. Supporting this view, for example, is the fact that in the developed world we shall soon enter an era in which almost all schoolchildren and university students, and large numbers of those entering the workforce will not have known life before the Internet. Even if they do not already use Internet-based services at home and at work, they will come to expect them as the norm, wherever they are.

The popular infocom services of today, such as telephony, e-mail and web browsing, are still for the most part capable of being delivered over communication networks that were designed for voice telephony and low-speed data communications. Broadly speaking, such networks, except for the most recently installed international links and a few national backbones are probably only going to be able to support the types of services that are in common use today. However, the new applications that are already being used or developed in universities and other R&D environments would typically require communications infrastructure that is capable of handling data rates that are orders of magnitude greater than are commonly available outside.

Despite the current gloomy forecasts of some analysts, there is still a clear global trend to develop and deploy new, innovative services. Nevertheless, before the economic and

[4] See ODTR Document 00/80 – "New issues in the Telecommunications Sector 2002- 2010" – presentation by A. Tumolillo, Probe Research Inc.

social benefits of the new applications can be realised, there would need to be very considerable increases in available bandwidth, especially at national level.

Therefore, one of the key challenges Ireland faces before it can derive the full economic benefits of the information age, including e-commerce, is to ensure there is sufficient broadband access to sufficiently high capacity backbone networks and international connections.

There are various technological options for providing last mile broadband infrastructure some of which are described in Appendix A. For the most part, these have already received much attention from the industry and regulators. However optical wireless, the subject of one of the briefing notes presented here is an exception to this. While this technology is already used in private networks to a limited extent, it seems there may be significant replication opportunities for it in Ireland. Perhaps even more importantly, it would appear that optical wireless may also be capable of helping tackle the problem of last mile broadband access. *We would be especially interested in hearing the views of private and public network operators, service providers, equipment manufacturers and end users on the possible roles that optical wireless systems might play in helping bring broadband access and services to consumers.*

[5] Alongside for example electric power, combustion engines and semiconductors.

3 Briefing Notes

3.1 Optical Wireless Technology

3.1.1 Introduction

Given the increased demand for high bandwidth applications such as video conferencing and media streaming, network designers are faced with the task of ensuring that their networks are capable of supporting such applications, as well as ensuring that their networks can withstand future growth in traffic. In planning their networks, designers are faced with a number of technological choices both in terms of hardware and software. In terms of hardware, possibly the most important decision to be made is that of the transmission media to be deployed in order to facilitate communication. The transmission medium provides the connection between the network nodes (e.g. computers) and it is this medium that determines how fast and how much information may be transferred across the network. There is a wide range of different transmission media available but these may broadly be categorised into wired or wireless media.

3.1.2 Wired and Wireless Technologies

Traditional computer networks typically consisted of copper cable connections between the network nodes and the network. These networks typically supported bit rates of less than 10Mbit/s. In recent years however, bit rates in excess of 100Mbit/s have been required to support applications such as voice and video. Achieving data rates in excess of 100Mbit/s over copper requires the use of high-grade copper cabling e.g. Category 5 or 6. Designers may choose to upgrade existing copper lines to such higher grade cabling or may decide to migrate away from copper altogether.

In recent years, there has been increasing evidence of migration from copper media to alternative wired solutions such as optical fibre and wireless solutions. Fibre has a greater capacity than copper and it therefore often represents a more attractive medium for supporting new and innovative applications. However, replacing copper with fibre presents a number of problems in itself. Indeed replacing any cable media presents its problems. Copper and fibre replacements are costly and deployment may be subject to delays in both the planning and physical installation stages. Planning permission must be sought and construction companies employed to dig up streets.

Wireless technologies on the other hand by-pass the need for disruption of roads and thus may be deployed rapidly.

3.1.3 General Description of Wireless Systems

Wireless solutions are available using radio[6], microwave and optical wireless methods. Where relatively low data rates are concerned then radio systems operating in frequency bands up to UHF can be used. However, where high bandwidth is required then microwave or optical systems are often deployed. Microwave systems have been in use commercially for many years and their operation and reliability is widely documented.

Optical wireless systems are less widely used but seem to be becoming more prevalent, again largely as a result of growing demands for the seamless support of multimedia applications. In Ireland, an exact figure of the number of systems of this type in use has not yet been determined conclusively but it seems that they are still few in numbers.

3.1.4 Operation of Optical Wireless Communication Systems

In optical wireless communication systems communication is facilitated by the superimposition of information onto a carrier signal with an operating frequency that lies in the optical region of the electromagnetic spectrum (between 10^{11}Hz and 10^{16}Hz). This signal is generated by either a Light Emitting Diode (LED) or a laser diode and is propagated outward into the atmosphere. A receiver intercepts the optical signal some distance away allowing the information to be extracted.

3.1.5 Advantages of Optical Wireless Technology

The bandwidth of a signal describes the frequency range that it occupies. As stated, optical systems are inherently high in bandwidth, operating between frequencies of 10^{11}Hz and 10^{16}Hz. In terms of data rates, optical wireless systems are typically used to support data rates of 155Mbit/s, 622Mbit/s and even Gigabits per second, thereby making them an attractive networking solution for broadband connections.

In terms of coverage, current optical wireless systems are capable of operating up to a distance of 6km, which means that they offer feasible networking solutions for Local Area Network (LAN) and Metropolitan Area Network (MAN) connections.

Another advantage of optical wireless systems is that they provide line of sight communication through a narrow beam which cannot easily be intercepted. This means that they provide good security from eavesdroppers. Adding encryption serves to increase the security of information transferred over the optical wireless link.

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[6] Here the term 'radio' refers to radiocommunications at frequencies up to and including UHF (up to 3000MHz).

Optical frequencies are not regulated. For a private network into which optical wireless systems are incorporated, there is no requirement for the owner of the network to hold a Wireless Telegraphy licence. However, if the network is to be used for the provision of telecommunication services to the public, either a basic or a general telecommunications licence is required[7].

3.1.6 Disadvantages of Optical Wireless Technology

As with all technologies, optical wireless too has its limitations. Reservations have been expressed about the reliability of optical wireless systems under adverse weather conditions such as rain or fog, as well as the likely impact of sunlight on the reliability of the system. The industry has recognised that these problems exist and by and large claim that these problems may to an extent be overcome by taking a number of reasonable and precautionary measures including:

- Limiting the range of the link
- Implementing a redundant path for communication in case of failure of the link
- Avoiding deployment of the optical wireless links in an East-West orientation so that a rising or setting sun cannot temporarily block the receiver
- Implementing reliable transmission protocols such as TCP/IP to ensure that any information packets lost if a disruption occurs get resent.

3.1.7 Manufacturers

There are several manufacturers of optical wireless systems, and links to the web sites of some of these are included without endorsement by the ODTR in the bibliography below.

3.1.8 Costs of Optical Wireless Systems

In terms of costs, our preliminary analysis would seem to indicate that optical wireless systems could be an attractive solution in many situations. For example, in some cases they would appear to offer the prospect of considerable savings compared to the equivalent costs for leased circuits.

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[7] Further information on the telecommunications licensing in Ireland can be found in the following ODTR documents which may be accessed via the ODTR website at http://www.odtr.ie :
98/46R "General Telecommunications Licence - Application form",
98/45R "Basic Telecommunications Licence - Application form",
98/44R "Telecommunications Licences - Guidance Notes for Applicants"

3.1.9 Possible Scenarios for the use of Optical Wireless Technology

Figure 1 depicts a possible scenario using optical wireless as the communications medium of choice between an Internet Service Provider and a number of customers. The home computers of the customers are connected to a close-by concentration point which is in turn connected be means of an optical wireless line of sight link with the local Internet Service Provider.

Figure 2 shows the use of a line of sight optical wireless communications link that provides communication between buildings, e.g. linking offices or campus buildings.

Figure 3 shows the use of an optical wireless system to provide communication between three buildings. Building A and B have line of sight links between them but buildings A and C have no unobstructed line of sight paths; trees in a public area on the hill block a possible line of sight path. Using two optical wireless links at building B however allows for the possibility of communication between building A and C indirectly.

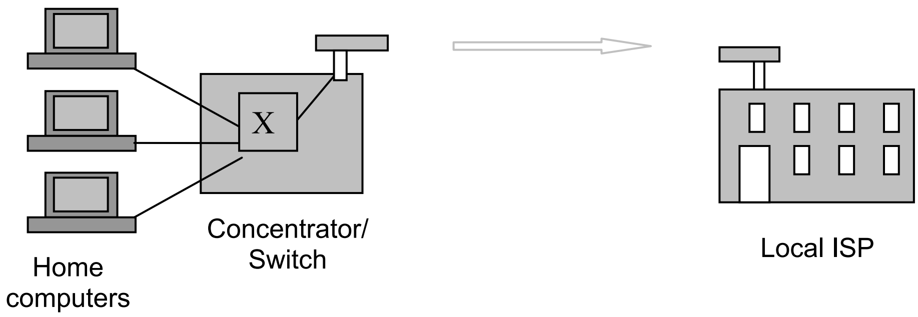

Figure 1

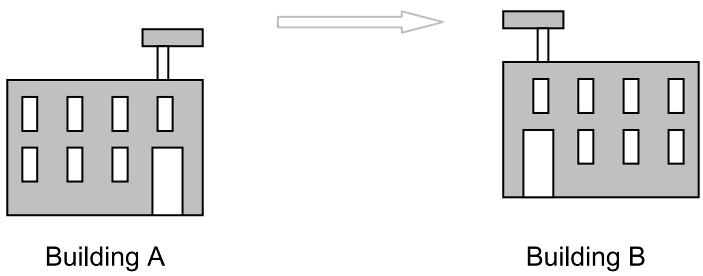

Figure 2

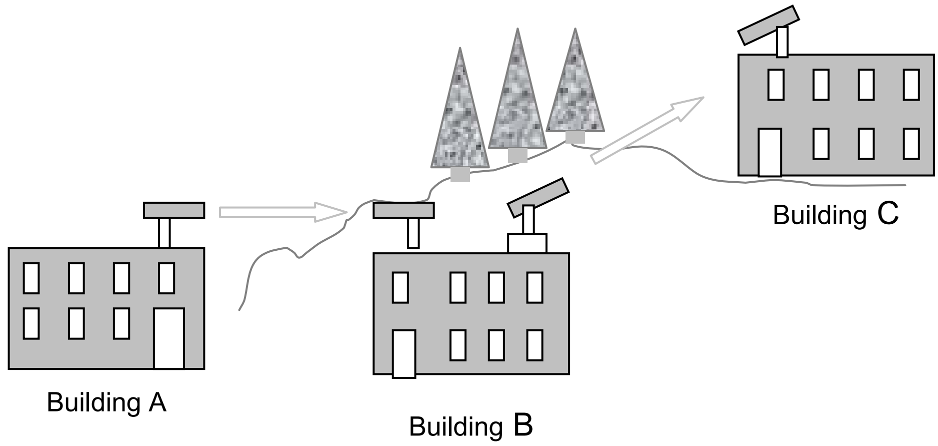

Figure 3

3.1.10 Conclusion

In summary, it would seem that optical wireless systems could prove to be a cost effective and timely networking solution for many users requiring broadband connectivity. The technology boasts a number of advantages including high capacity, high security, high reliability when properly maintained, exemption from Wireless Telegraphy licensing, and ease of maintenance.

They also appear to represent an attractive solution from the point of view of flexibility and time to deploy. They are relatively easy to install and may be mounted at almost any location, provided line of sight is available. Furthermore, a maximum period of one day for installation is quoted from suppliers. On the other hand, where leased line provision is required, deployment may take several weeks or months.

While optical wireless, like other transmission media, has its limitations, it seems that most of these problems can be avoided or at least minimised by careful design and maintenance.

3.1.11 Bibliography/Further Information

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K. Washburn and J. Evans, 'TCP/IP, running a successful network', 2nd Edition, Addison-Wesley, 1996, UK

Some Manufacturers[8]:

AEI Wireless Communications - http://www.aeiwireless.com/
Cablefree Solutions Ltd. - http://www.cablefree.co.uk/
Infrared Communications Systems Inc. - http://www.infraredsystems.net/
Optical Access Inc. (previously Jolt) - http://www.opticalaccess.com/
LightPointe Communications Inc. - http://www.lightpointe.com/
Optel GmbH - http://www.optel.de/
Pav Data Systems Ltd. - http://www.pavdata.com/
CBL GmbH - http://www.cbl.de

Related hyperlinks

http://www.lightreading.com/document.asp?doc_id=3124
http://www.lightreading.com/document.asp?doc_id=1665
http://www.lightreading.com/document.asp?doc_id=1207

http://www.nwfusion.com/newsletters/optical/index.html

[8] This list is not intended to be exhaustive. It is provided for information purposes only.

3.2 Ultrawideband (UWB) Communications

3.2.1 Introduction

The term ultrawideband (UWB) communications covers two main types of application. First, these can be short-range in-building type devices potentially capable of competing with current Wireless LANs and Bluetooth technologies (in the frequency range 1 to 6 GHz). Secondly the technology is applied to a new generation of short range radar devices (~ 24 GHz). Radar applications of this type include for example level gauges in industrial process storage tanks and collision detection devices for cars.

The concept of UWB is as follows; instead of transmitting information on a continuous specific carrier frequency, short pulses are transmitted in sequences (Pulse Position Modulation), representing information bits. The shorter the transmitted pulse (~ 0.5 nanosecond), the wider the bandwidth of the signal. The main idea here is that the bandwidth will become so wide (~ 2 GHz), and the energy so spread out across the spectrum, that its presence will be undetectable to traditional frequency selective radio systems. This property, in the view of the UWB proponents, will allow UWB systems to be deployed in parts of the spectrum where other services already exist and will allow them to share the same bands undetected. The issue is whether or not such systems can co-exist with traditional radio systems without causing, or suffering from harmful interference.

3.2.2 Advantages of this Technology

When used for communications applications, this technology offers the possibility of high transmission rates (up to 100Mbit/s), at low power densities, without the need for exclusive or even protected spectrum. In theory UWB systems could be freely implemented without the need for frequency planning as their presence would not be detectable by traditional receivers.

When used for radar applications, UWB technology offers the possibility of low powered effective radar systems (including hand held devices) that would not disrupt other services significantly. In addition to this, pulsed (UWB) radar systems have the capability to produce very high resolution results, particularly when being used for ground penetration or through-wall applications.

3.2.3 Disadvantages of this Technology

The use of a large amount of spectrum, albeit at a very low power level, still requires the use of a valuable resource. Some may view this technology as a form of spectral pollution which takes the approach of limiting rather than avoiding interference.

The effect of UWB systems on existing radio systems is as yet unknown, and measuring techniques have yet to be developed to successfully demonstrate the impact of UWB systems on other radiocommunication systems.

There are many unknowns when considering the effects of pulsed-transmissions on radio receiver equipment, including the individual behaviour of particular materials when subjected to transient pulses and the combined effects of many responses from different materials and circuit elements. In particular, little is known about the potential effects of the introduction of a large number of UWB systems. There are concerns that the use of a large number of such devices in a location may increase the ambient noise floor to unacceptable levels.

Another important issue is the resilience of the UWB receiver to the emissions of conventional radio transmitters. If UWB receivers are designed to detect signals with very low power densities (below the noise floor of conventional receivers) it can be expected that they could be more susceptible to interference noise than conventional narrower band receivers, although the signal processing capabilities of the system should cope with a certain amount of high level relatively narrow band interference (as in a more conventional CDMA system).

3.2.4 Overcoming these Problems

These problems are inherent to ultrawideband technology and in general cannot be overcome through technological innovation solely in the ultrawideband field. Specific protection could be given to existing radio systems at individual frequencies through advanced coding or filtering techniques in ultrawideband systems, but protection of multiple systems would be impracticable. The issue really is whether or not these potential interference problems will materialise. Therefore to evaluate thoroughly the potential impact of UWB systems more studies would need to be carried out.

3.2.5 Licensing Issues

Due to their low levels of emitted power and expected mass distribution UWB systems could be treated in a similar manner to short range devices in most countries and may therefore be eligible for exemption from licensing requirements[9]. In Ireland, and other countries, possible licensing approaches are currently under consideration. In the case of UWB radar systems, certain restrictions on the usage methods may need to be employed (e.g. a device may only transmit when in contact with the surface being surveyed).

3.2.6 Implications for the Irish market

If ultrawideband is introduced to the Irish market its potential market development impact could be significant, particularly for short range wireless applications (e.g. Wireless LAN) and in advanced automobile systems (e.g. short range collision detection and avoidance radar systems). Such applications could be of significant social benefit, by helping to increase safety on our roads. Other applications may emerge in due course.

3.2.7 Conclusion

It would appear that UWB will in the future offer a convenient way of overcoming some spectral resource problems. However, at present, not enough is known about its operation and the impact it will have on existing radio systems. So for the time being, any decisions concerning deployment of this technology would need to be carefully considered.

3.2.8 Bibliography

Terrence W. Barrett, "History of Ultra Wideband Communications and Radar (Parts I and II)", Microwave Journal, January & February 2001.

National Telecommunications and Information Administration (NTIA), *"Assessment of Compatibility between Ultrawideband Devices and Selected Federal Services",* U.S. Dept. of Commerce, NTIA Special Publication 01-43.

National Telecommunications and Information Administration (NTIA), *"Assessment of Compatibility between Ultrawideband Systems and Global Positioning System (GPS) Receivers",* U.S. Dept. of Commerce, NTIA Special Publication 01-45.

[9] Depending on national regulations and the results of sharing studies.

3.3 High Altitude Platform Stations (HAPS)

3.3.1 Introduction

High Altitude Platform Stations (HAPS)[10] potentially offer a new way of delivering broadband radiocommunications services that could help ease some of the roll out and capacity problems faced by today's telecommunications network operators within the next five years. These systems bypass the need for the roll out of extensive access and back-haul networks. Furthermore, HAPS systems can provide instant coverage once launched and have no need for expensive launch vehicles as in satellite systems[11].

The concept is that a user on the ground is connected to a telecommunications network through a repeater or base station mounted on a platform (i.e. HAPS) high above them in the sky, see figure 1 below. These platforms can be aeroplanes, helicopters or balloons. On the network side a HAPS is directly connected via a radio link to a gateway to the terrestrial network. HAPS can typically be positioned at an altitude of 21km (most systems under development are at altitudes between 15 and 25km) above a service area, yielding a coverage area of 19000 square km (155km diameter). The idea is to mimic the functionality of a satellite without incurring the huge financial costs (e.g. less expensive equipment, no launch vehicle needed, large area coverage) or the significant propagation penalties (i.e. due to shorter transmission distances).

[10] A high altitude platform station is defined in the ITU Radio Regulations as a station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth.

[11] Satellite launch costs are typically over 150 million Euro for a single satellite. With insurance costs sometimes in excess of launch costs the total cost of launching a satellite can be of the order of hundreds of millions of Euro.

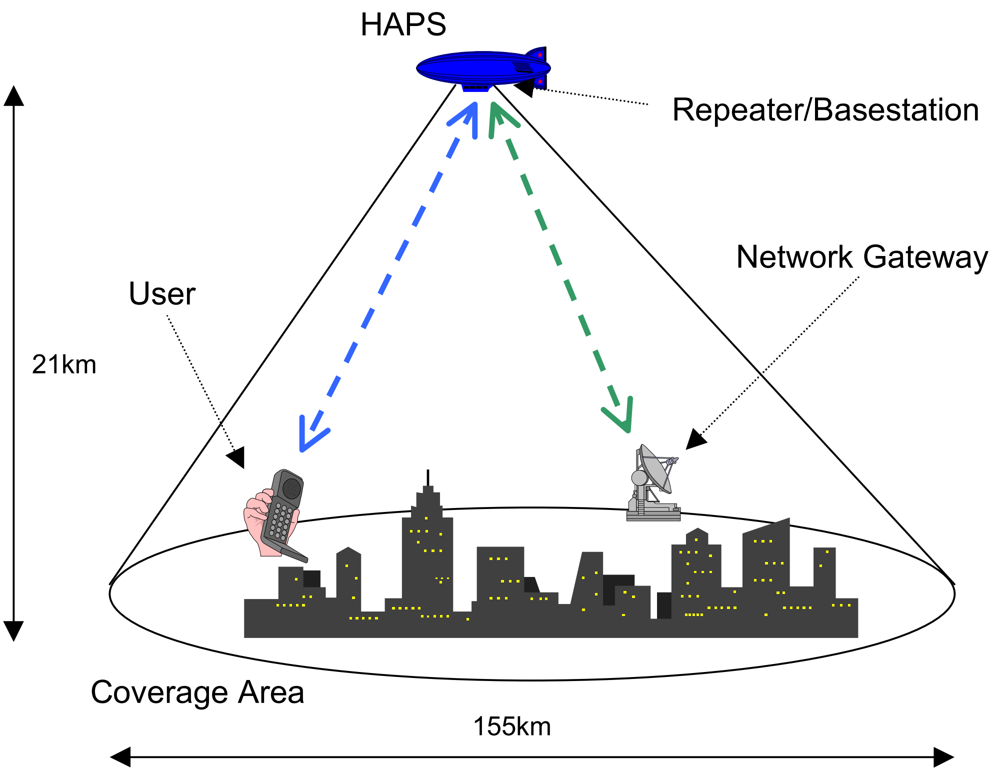

Figure 1. A HAPS system covering a city.

3.3.2 Approaches

There are currently two main approaches to the development of HAPS; aeroplanes and balloons. The aeroplane option is being developed in light of recent technology advances in lightweight aviation technology and in un-manned flight resulting from mostly military applications. The types of systems that are proposed involve small fleets of aircraft (e.g. two or three) each able to stay in operational position for approximately 24 hours before having to come down to refuel, while being replaced with another identical aircraft.

With the balloon solution large airships (approximately 160 metres long and 60 metres in diameter) could carry the communications equipment to the required stratospheric altitude and remain in position for periods of up to 10 years. Since these balloons would operate within the earth's atmosphere, unlike an orbiting satellite, they could be easily retrieved for servicing or upgrades.

3.3.3 Applications

The main applications under development for HAPS are:

- **Mobile** – specific spectrum has been identified for HAPS in IMT-2000(3G), see Frequency Allocation section.
- **Fixed Wireless Access** – broadband access, up to 155Mbit/s or higher.

Other likely applications for HAPS are:

- **Low cost telecommunications for developing countries** – low cost with minimal infrastructure requirements.
- **Broadcast services** – metropolitan or region wide coverage.
- **Disaster Relief** – rapid deployment of communications for relief workers where existing telecommunications infrastructure may be insufficient or inoperable.
- **Earth sciences** – inexpensive environmental studies (e.g. crop densities, radiation detection, road traffic patterns).

3.3.4 Advantages

Coverage

At an altitude of 21km a HAPS could have a coverage area of 19000 square km which represents a circular region of 160km in diameter. The high altitude of a HAPS would also yield a direct line of sight from most city streets and from any roof top to the HAPS. Lower altitude aeroplane implementations typically have smaller coverage areas, depending on their altitude.

Furthermore, the coverage area could be dynamically altered by either relocation of the HAPS or by redirection of its antennas. This could help accommodate situations where more capacity may be needed in a city centre during the day and in the suburbs during the night.

Network Roll-Out

Lengthy delays associated with the roll-out of back haul networks can be the most significant factor holding back the provision of telecommunications services, with increasingly difficult delays due to site acquisition, planning permission and facilities construction. Via a HAPS, users can be connected directly to a network gateway, bypassing the need for a back haul network. This means that once the HAPS is in position services can be provided instantly to users with terminals anywhere within the entire coverage area.

Capacity

To provide the required capacity the coverage area of a HAPS can be divided into multiple smaller coverage areas (e.g. 16km diameter) using highly focused spot-beams (e.g. 700 beams per HAPS), allowing better utilisation of spectrum through frequency re-use. Furthermore the high altitude of the platforms also allows for the provisioning of more focused beams which aids frequency re-use.

Currently planned systems expect to offer between 2 and 10 Mbit/s data rates to users. More advanced systems should offer 155 Mbit/s access.

Maintenance/Upgrades

A particular advantage of HAPS systems is their accessibility in terms of maintenance. If a HAPS develops a problem while in service, it can simply be brought back down to the ground and repaired, while a replacement HAPS can be put into place to ensure that there is minimal disruption to service. This sort of maintenance is not possible with satellite systems. Furthermore, if the HAPS equipment needs to be upgraded to provide new or improved services the HAPS can similarly be easily accessed. In the case of satellite communications the same level of flexibility does not exist and implementation of such systems is therefore inherently more risky from an economic point of view.

Environmental Aspects

The advantages of operating in the stratosphere over terrestrial based communications include the lack of precipitation[12] (i.e. rain, moisture) and lower wind speeds (at an altitude of 21km). Low wind speeds mean that balloon implementations require very little energy to remain in a fixed position. In comparison to space based communications HAPS will not require expensive radiation-hardened electronics since the stratosphere is more favourable in this respect also.

3.3.5 Limitations

Power

Currently the main limitation factor of HAPS is power, which is needed for a platform to stay in position and offer communications services. Research is currently being carried out in the areas of fuel-cell technology and advanced solar power techniques to solve this problem. The solar power option is perhaps the most promising, but energy must be

[12] Although precipitation at these altitudes is less likely to collect on the antenna systems, some rain fading will

stored to keep the platforms operational during the night and increased cloud cover at latitudes further from the equator is also a significant factor. Aeroplane implementations require even more power to remain in flight.

Stability of HAPS

Ideally HAPS would be located at fixed geostationary positions above the earth's surface. In the case of aeroplanes, this is not possible due to the need to stay airborne and such a HAPS could therefore be travelling at speeds of up to 100km/hour. This would require adaptive re-adjustment/tracking of antenna patterns, both on the HAPS and in some cases on the ground[13] (e.g. gateway stations).

High Altitude Problems

Other technical difficulties arise from environmental conditions in the stratosphere. Low atmospheric pressure at high altitude (approximately 200 times lower than at ground level, i.e. ~ 5hPa[14]) requires larger airships to carry a particular load. Plasma (ionised gasses) effects in the atmosphere can reduce the efficiency of solar cells and affect the operation of electromagnetic equipment.

Although most HAPS operating at an altitude of 21km would be above commercial air traffic, consideration would have to be given to air traffic at lower altitudes.

Rain Attenuation

Attenuation or fading of radio signals due to the effects of rain and precipitation become more significant at some of the higher frequencies (i.e. >10GHz) that HAPS can operate at and this is therefore a limiting factor in the design of such systems. These effects are more critical in regions with more severe levels of rainfall (e.g. tropical regions). However, rain fading would be more severe in terrestrial systems due to longer path lengths through the rain.

occur in the lower atmosphere.

[13] For mobile terminals omni-directional antennas are typically employed, which would not require tracking.

[14] Hecto Pascals (hPa) are a measure of atmospheric pressure. 1 hPa = 1 milli-bar. Pressure at sea level, in Ireland, is typically 1013hPa or approximately 14 pounds/square inch.

3.3.6 Frequency Allocations

Frequency allocations for HAPS were made at WRC-97[15] and WRC-2000, and the issue will be raised again at WRC-03. Originally 600MHz of bandwidth in the 48GHz[16] region was allocated for HAPS. More recently at WRC-2000 HAPS were specifically identified as a platform for providing IMT-2000[17] (3G) services and 170MHz of spectrum was made available in the 2GHz region[18] through a footnote to the radio regulations[19].

Further studies are being carried out on the use of HAPS at 28 and 31GHz regions and these will be considered at WRC-2003[20]. It has also been suggested (by Japan) that HAPS could operate at practically any frequency shared with terrestrial services (fixed and mobile) above 3 GHz[21] and sharing studies are to be carried out. The possibility of interference with amateur services in an adjacent band at 48GHz has also been raised along with possible negative implications to radio astronomy services. Sharing studies are being conducted in these areas also.

3.3.7 Conclusion

Currently systems are still under development and refinements in solar power technology and adaptive antenna systems are needed before these systems are viable. However, some systems have been tested (e.g. *ARC System - Platforms Wireless International Corporation, Los Angeles*) and it is expected that services will be offered in Brazil this year (*Americel, Brazil*). In general the near term HAPS solutions involve less developed technology such as manned aeroplanes and tethered balloons operating at lower altitudes. However, experience gained from these projects will help develop and determine the commercial viability of future HAPS systems.

Although HAPS developers claim that their systems will be ready within the next two years (see Annex 1) it is more likely that systems will not be deployable until between

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[15] International Telecommunications Union (ITU), World Radiocommunications Conference (WRC).

[16] 47.2 – 47.5 GHz paired with 47.9 - 48.2GHz. Resolution 122 (WRC-97)

[17] Time Division Duplex (TDD) IMT-2000 modes cannot be used over HAPS systems due to the time delay caused by the HAPS distance from the earth.

[18] 1.885 –1.980 GHz, 2.01 – 2.025 GHz and 2.11 – 2.17 GHz. Resolution 221 (WRC-2000)

[19] S5.888A

[20] Agenda Item 1.13

[21] WRC-2000 Resolution 734

three to five years from now, particularly in regions at higher latitudes[22] (i.e. Ireland). Some important practical operational issues are still yet to be proven (e.g. stability of platforms, power consumption and system link budgets).

Irish Implications

For a country the size of Ireland HAPS systems could provide region-wide coverage of broadband access services (possibly up to 155Mbit/s) once the technology has matured sufficiently. HAPS could also assist with the roll out of FWA and mobile services. An implication of HAPS for a country the size of Ireland is that, unlike satellite systems, they can be employed using a system's full capacity for national services.

3.3.8 Bibliography/Further Information

Angel Technologies, www.angelhalo.com

ITU-R M.1456, "Minimum performance characteristics and operational conditions for high altitude platform stations providing IMT-2000 in the bands 1885-1980MHz, 2010-2025MHz and 2110-2170MHz in Regions 1 and 3 and 1885-1980MHz and 2110-2160MHz in Region 2"

Platforms Wireless International Corp., www.plfm.net

SkyLarc Technologies, www.skylarc.com

Skystation International Inc., www.skystation.com

3.3.9 Annex 1 – Examples of HAPS systems under development

System	Company	Technology	Altitude km	Implementation Date[23]
ARC (Airborne Relay Communications) System	Platforms Wireless International Corp., Los Angeles	Tethered Balloon, solar power, unmanned	4.5	2001
Sky Station	Sky Station International Inc., Washington DC	Balloon, Solar Power, Unmanned, 2 – 10 Mbit/s	21	2002

[22] see section on power limitations.

[23] These projected implementation dates are taken from the companies' media releases.

HALO (High Altitude Long Operation)	Angel Technologies, St. Louis	Aeroplane, turbo-prop, manned, 1.5 – 12.5 Mbit/s	16	2003
StratSat	Advanced Technologies Group, Bedford, UK	Balloon, unmanned.	21	2003

3.4 Broadband VSAT (Very Small Aperture Terminals).

3.4.1 Introduction

A VSAT (Very Small Aperture Terminal[24]) is a communications terminal that can be easily installed on the roof of a user's premises and used to access a wide range of telecommunications services such as broadcast video and internet access. The provision of these types of services is the subject of a recent £1.5 million VSAT internet pilot project launched by the Department of Public Enterprise[25] (24th of July 2001).

VSATs communicate through orbiting satellites[26], relaying information to and from controlling gateway[27] stations known as hubs. VSATs can offer low cost, easy to install solutions for areas with limited telecommunications infrastructure (e.g. rural areas) due to the large coverage areas offered by these satellite systems.

Recently VSAT networks have been able to offer limited two way "broadband"[28] services. This market is growing and systems are currently being developed that will provide higher broadband access rates.

3.4.2 How VSATs work:

VSAT terminals belonging to a particular VSAT network are connected together via radio links through a common point in the sky (i.e. the satellite). Terminals which are part of a VSAT network can communicate with one another as part of a closed user group (e.g. private corporate communications), or with other networks (e.g. the internet) through a gateway hub station. The individual VSAT terminals are remotely controlled from the hub (see figure below) and the network can be formed with different topologies (e.g. Star, Mesh[29]).

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[24] The term VSAT stems from the size of the satellite terminal's antenna or dish, which is generally very small relative to traditional satellite earth stations (approx. 2 metres). A VSAT however is defined by more characteristics than just antenna size, such as networking and control details.

[25] See www.irlgov.ie/tec/july24th01.htm and www.irlgov.ie/tec/communications/vsat.htm

[26] Typically these are geostationary satellites orbiting 36,000km above the equator which maintain their positions relative to a point on the Earth's surface.

[27] A gateway is a point on a telecommunications that provides access to other telecommunications networks.

[28] Many VSAT services marketed as broadband may only be broadband in the downlink direction, and available capacity may vary according to usage patterns (see **Low Capacity** section).

[29] Most VSAT networks implement Star configurations requiring all communications to pass through the hub station. Mesh configurations allow VSAT to communicate with one another directly.

In order for an operator or service provider to offer VSAT services they must have access to spectrum on a satellite. This means that the operator must own its own satellite or else lease capacity on a satellite operator's satellite[30]. The service provider would then be able to provision services over this satellite to its customers.

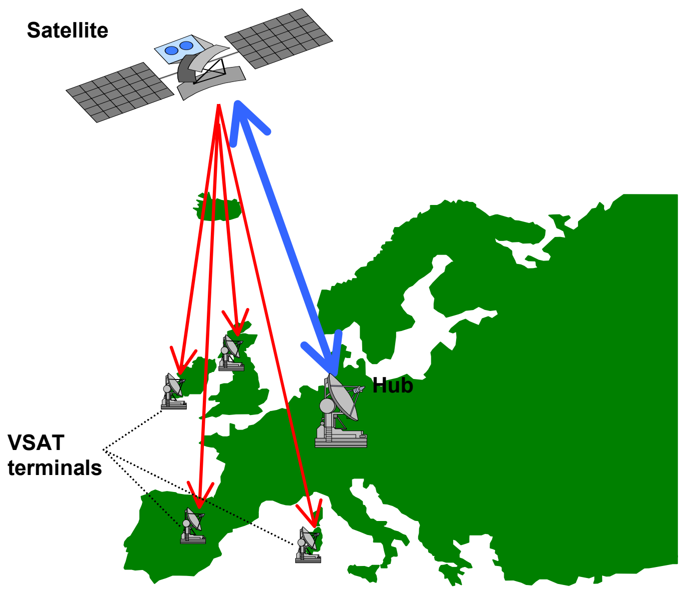

Figure 1 – A European wide VSAT network

3.4.3 Advantages

Easy Deployment

VSAT installation is simple due to their compact size and wireless nature (e.g. suitable for home deployment).

Rural Deployment

VSAT systems are particularly suited to provisioning of services in areas where telecommunications infrastructure may be limited (e.g. rural). Here services can be quickly deployed without the need for an extensive and costly infrastructure roll out (e.g. remote bank branches).

[30] Operators who own and operate satellites (i.e. space craft) are known as space segment operators.

Diversity

Diversity from terrestrial network infrastructure[31] is a key advantage of satellite systems in the event of terrestrial network failure. Furthermore, independence from terrestrial networks makes VSATs ideal in many disaster recovery situations.

3.4.4 Disadvantages

Low Capacity

The limitation of spectrum for satellite services and orbital positions places major restrictions on the amount of capacity available to VSAT users (See Spectrum Issues below). Current VSAT systems typically offer capacities of a few hundred kbit/s up to 2 Mbit/s in the downlink direction (toward the user) with lower capacities of between 64kbit/s and a couple of hundred kbit/s in the uplink direction (See Annex 1). Furthermore, user capacities are often dependent on the number of active users and the levels of service that they require. For example, a full 2Mbit/s downstream data rate may not be available to individual users if there are multiple users who all require high capacities simultaneously.

Next generation systems will have increased capacities. See Future Developments section below.

Voice communications & Latency

Due to the long distances that signals have to travel up to a geostationary satellite and back down to earth again (at least 72000km) a delay of approximately a quarter of a second is experienced[32]. This is a fundamental limit that makes this type of system unsuitable for high quality voice communications in many cases. The effects of latency on internet data applications are less significant.

3.4.5 Spectrum Issues

Currently most VSAT services operate in the Ku-Band (10.7-11.7GHz, 12.5-12.75GHz Downlink, 14-14.5GHz Uplink). Some sections of these bands are also used for terrestrial fixed microwave links. VSAT services will continue to grow in these bands for the foreseeable future.

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[31] Since the VSAT network will in most cases connect into terrestrial networks at some point it is not totally independent.

[32] A further quarter of a second can be added to the total delay (i.e. half a second) for the time the reply takes to arrive.

Other VSAT systems are planned for the Ka Band (17.7 – 22.2GHz downlink, 27.5 - 31GHz uplink). There is more bandwidth available at these higher frequencies which yields greater capacities, and it is expected that high density services such as home internet access will develop. Certain portions of spectrum in these bands are also shared with fixed links and there are European measures (i.e. ERC decisions[33]) that allocate these bands more specifically.

3.4.6 Future Developments

Currently all of the major space segment operators (i.e. satellite operators) are developing or testing Ka band satellites with broadband capabilities. Although some doubt exists over the ability of such systems to cope with the effects of rain attenuation at these higher frequencies, large numbers of these terminals are expected (i.e. High Density Satellite Service). See Annex 1.

In some future systems large adaptive antennas on the satellites themselves will enable multiple beams to re-use frequencies. This will greatly increase capacity and the number of users that can be accommodated per system. Such systems will not be deployable until at least 2004[34].

To overcome the problems of latency (see Voice communications) and to reduce power emissions new non-geostationary systems are planned for the provision of broadband VSAT services. These systems involve networks of multiple orbiting satellites that pass over the earth (i.e. appear to move across the sky) and are located at lower altitudes (e.g. Teledesic: 288 satellites at 1400km). These systems are complex and their feasibility is yet to be proven. Furthermore they will present complicated co-ordination and interference problems due to the non-geostationary nature of the satellites. The implementation dates of these systems are continuously being pushed back and there is doubt over whether they will ever be realised (See Annex 1). It is unlikely that any non geostationary systems will be implemented by 2004.

3.4.7 Market Implications

VSATs offer the greatest benefits to rural users and may play a significant role in developing rural regions in the near term, prior to more wide spread availability of

[33] ERC: European Radiocommunications Commission - Decisions 00(07), 00(09)

[34] By this time adaptive antenna technology will also have increased the capacity of terrestrial networks.

terrestrial broadband infrastructure. VSAT systems are less competitive in urban areas where alternative methods of broadband access exist.

3.4.8 Licensing in Ireland

Currently VSAT terminals are required to hold a Wireless Telegraphy licence for transmissions[35]. The receiving portion is exempt from licensing. Furthermore there is an ERC[36] decision that would allow for the exemption of the transmitting portion, in a certain dedicated VSAT band which covers most of the VSATs that the ODTR currently licences. Next generation VSATs operating at higher frequencies in the Ka band are also covered under the current regime, however there are ERC decisions recommending the exemption from licensing of some of these terminals also (i.e. SITs[37] and SUTs, see Annex 1). VSAT systems that provide services to the public may also be subject to telecommunications service licensing[38].

3.4.9 Conclusion

VSAT systems can provide instant access to broadband services in areas where terrestrial alternatives are not competitive or available. Furthermore these networks offer diversity in the provisioning of telecommunications services yielding resilience to terrestrial network faults.

However VSAT technologies are ultimately limited in terms of capacity and therefore may have difficulty sustaining long term success in an environment with competing terrestrial networks. New broadband VSAT systems are being developed which have more competitive access capacities. These should begin to emerge within the next two years.

3.4.10 Bibliography/References

Global VSAT Forum: www.gvf.org

Guidelines for applicants for satellite earth station licences in the fixed satellite service in spectrum above 3GHz: http://odtr-web/docs/odtr0064.doc

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[35] Statutory Instrument No. 261 of 2000, "Wireless Telegraphy (Fixed Satellite Earth Stations) Regulations, 2000".

[36] ERC Decision 00(05).

[37] SIT: Satellite Interactive Terminal, SUT: Satellite User Terminal.

[38] See www.odtr.ie documents 98/44R, 98/45R, 98/46R for further information on Telecommunications Service Licences.

Opening the market for satellite services – Report on the consultation: http://odtr-web/docs/odtr9949.doc

Teledesic: www.teledesic.com

3.4.11 Annex 1

Examples of major VSAT operators:

Name	Band	Uplink	Downlink	Start Date
Websat Limited	Ku	64kbit/s	Up to 8Mbit/s	In service
Direcway (HNS)	Ku	256kbit/s	Up to 24Mbit/s	In service
Gillat Satellite Networks	Ku	153.6 kbit/s	3Mbit/s – 52.5Mbit/s	In service
Eutelsat	Ku	2.4kbit/s – 8Mbit/s	2.4kbit/s – 8Mbit/s	In service
Tachyon	Ku	256kbit/s	2Mbit/s	In service
Wild Blue	Ka	400kbit/s	3Mbit/s	2002 (US)
Astrolink	Ka	20Mbit/s	155Mbit/s	2003
Spaceway, HNS	Ka	512kbit/s – 16Mbit/s	30Mbit/s	2003

Examples of planned NGSO (Non Geostationary) Systems

Name	Freq. Band	Uplink	Downlink	Service Date
Teledesic	Ka (19/28GHz)	2Mbit/s	64Mbit/s	2005
Skybridge*	Ku (10/14GHz)	10Mbit/s	100Mbit/s	2003

* Skybridge has recently announced that it will focus on providing Internet backbone services using leased satellite capacity.

ERC Decisions on SITs and SUTs.

SIT – *Satellite Interactive Terminal*: Interactive TV. Uplink: 29.5 – 30 GHz (Ka band), Downlink: 10.7 – 12.75 GHz (Ku band). ERC DEC 00(03).

SUT – *Satellite User Terminal*: Internet Access, broadband services. Uplink: 29.5 – 30 GHz (Ka band), Downlink: 19.7 – 20.2 GHz (Ka band). ERC DEC 00(04).

3.5 Software Defined Radio (SDR)

3.5.1 Introduction

Software Defined Radio (SDR) is an emerging radio technology that is more flexible than traditional radio technologies, in terms of how and what services can be provided to users. Currently radio devices are typically constructed from electronic components, which are assembled and configured in the factory to operate in a particular way (i.e. a GSM handset). If a user wants to avail of new or different services (e.g. GPRS or WAP), which their current radio terminal was not designed for, they have to purchase new equipment. Similarly, if a network operator wishes to provide a new type of service as well as, or instead of, existing ones (e.g. GPRS instead of GSM) they have to replace each individual base station with new equipment at considerable cost. SDR can overcome this problem.

An SDR can be modified to operate different types of services at any time after it leaves the factory. This is because the type or use of the radio is "defined" by the software that it runs and new software can therefore be downloaded and installed to change the radio's characteristics (e.g. GPRS software instead of GSM software). Furthermore it will not be necessary to return an SDR to the manufacturer or vendor for such modifications since new software will be downloadable over existing radio networks[39]. Similarly, if a network operator's base stations were all SDRs, they could be modified to operate a different type or set of services at any time[40].

By implementing more of a radio's functions in software code, instead of in rigid pieces of electronic hardware, the concept of SDR can, in theory, be applied to any radio system, operating in various frequency bands (e.g. GSM, 3G, Wireless LAN, TV, GPS all on one device). A device capable of operating in any frequency band is known as a Software Radio and is the ultimate target for SDR technology. This may not necessarily be achievable due to physical limitations (see Implementation Issues section), but ever more flexible radio devices will develop while pursuing this gaol.

It is useful to think of an SDR as being like a PC: a basic tool that can run various applications or programmes as needed. In the case of SDR, types of radio systems such as GSM and GPRS would be the applications, analogous to say Internet Explorer and

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[39] e.g. the SDR could be "taught" to operate as a GPRS radio using the GSM system it knows, analogous to how a person can learn a second language through their native language.

[40] See Implementation Issues section.

Netscape on a PC, i.e. either or both applications can be used on the same piece of equipment simply by downloading and installing the appropriate software.

Thus, the way SDR operates is inherently different to the way we implement and use wireless communications services today. This has important implications for industry and market development, and to the way in which spectrum is regulated and managed.

3.5.2 Background

The concept of SDR originally seems to have arisen from the needs of the US military to reduce the costs of operating a variety of different and incompatible radio systems. The idea here was that military radio systems could be built from commercial off the shelf (COTS) modules[41] thus greatly reducing the cost of developing, deploying and maintaining these systems [Capt. M. Gudaitis et al., 1997]. With this concept a generic and re-configurable model was proposed that would enable a device to be programmed to operate in any radio system (new or legacy). This would also eliminate the difference between military and civil radio products in terms of hardware, leaving the military security requirements up to the programming (both in terms of wave-form and encryption). Early SDR prototypes were developed by the US military in the mid 90's (SpeakEasy I and II).

Key to the successful adoption of SDR in civil or military environments is the availability of fully open standards and much care is being taken on the development of these standards to facilitate the maximum level of flexibility and interoperability. The SDR Forum[42] has been developing a core model for SDR.

3.5.3 Benefits of SDR

The ultimate benefits of SDR to the user are an increased availability and choice of services, deliverable in shorter time frames and at lower costs. The main benefits are covered below under the following headings:

- Choice of Service
- Risk Management
- Spectrum Issues

[41] Modules can be discrete pieces of hardware (i.e. individual chips or circuit boards). SDR modules also describe software objects.

[42] The SDR Forum is an industry body, formally know as the Modular Multifunction Information Transfer System (MMITS) Forum. www.mmitsforum.org

- Cost
- Emergency Services/Disaster Relief

Choice of Service

For the end user SDR will bring about choices of service through a single radio terminal that would otherwise have required multiple pieces of equipment operating through various operators or service providers. For example a user could configure their SDR to be used as a mobile phone one minute, a TV receiver the next, and then a GPS device[43]. The consumer will be able to select from a range of services and simply download a new service 'over the air'[44]. The availability of services to the consumer could then also develop along the same model as Application Service Providers (ASP), allowing specific services (e.g. location based services, wireless LAN services, internet services) to be subscribed to individually as and when required.

It is also worth noting that this SDR architecture provides for a terminal to operate several different radio services and interfaces simultaneously as the processing capabilities of the device are managed dynamically.

Risk Management

Deploying an SDR network is inherently less risky to system operators and service providers than the deployment of traditional hardware defined radio networks. The benefit comes from the re-programmability of the SDR system. An operator would be able to implement a certain type of radio network which if it is not successful or profitable after some time can be reprogrammed without the need to replace infrastructure or user hardware. This means that the 'fork-lift upgrade' will no longer be necessary as the entire network can be upgraded through reprogramming and over the air.

Spectrum Issues

SDR equipment, with the ability to operate in multiple bands[45], could potentially reduce spectrum congestion problems. An SDR can be reprogrammed to operate in different

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[43] It is also possible that an SDR device could operate as a fixed-line network device (i.e. a fixed telephone line could be plugged in instead of an antenna, or fibre optics equipment).

[44] The concept of 'over the air' means that the physical properties or protocol details of a new type of radio service can be simply transmitted to the user over an existing radio air interface, without the need to send a device back to the factory for upgrading.

[45] SDR could implement and expand upon the functions offered by dual-band or tri-band mobile handsets.

frequency bands (even during operation) enabling operators to dynamically avoid congested sections of spectrum and to exploit under-utilised frequencies. Entire networks could conceivably be developed with the ability to dynamically reconfigure their frequency usage for maximum efficiency and interference mitigation. Radio networks would therefore be implemented with a level of intelligence, enabling them to listen out for congestion before transmitting (see Cognitive Radio section).

Issues of spectrum re-farming or re-location of services would also become less of a problem as the time frames currently needed for the decommissioning of legacy equipment would be reduced to the time it takes to upgrade the necessary software on the network.

The benefits described above will require some developments in national and international regulation methods (See Regulation section below).

Cost

SDR should reduce costs in the radiocommunications industry. Development costs would reduce as new products and services become a matter of software development rather than relatively expensive semi-conductor design. For the operator and service provider the cost of deploying new services and upgrading should be reduced as existing hardware and infrastructure would not need replacing as often. These benefits, as well as the resultant increased competition in the market, would in turn reduce costs to users.

However, it is also possible that SDR users' hardware may regularly become obsolete due to ever more demanding software upgrades, as in the PC industry today. If this is the case SDR might only provide short-term cost savings to users.

Emergency Services and Disaster Relief

With the mass availability of SDRs, increased inter-operability will be afforded to different emergency services, allowing the police, fire and ambulance services etc. to work together more easily. For example a police radio could be re-programmed over the air to operate in conjunction with an ambulance service radio system resulting in increased communication and efficiency.

In cases of disaster relief, international civil and military radio systems could be quickly re-programmed to operate together. This would save vital time in a disaster situation by eliminating the need to deploy a new radio system physically for a co-ordinated relief operation (i.e. sourcing and distribution of radio terminals).

3.5.4 Regulation

The potential ability of SDRs to operate at various frequencies would enable the frequency management process to be improved, since SDRs could have the ability to monitor radio traffic before attempting to use a frequency (i.e. listen before talk) thus avoiding interference. However, to facilitate SDR, international and national regulations and frequency assignments would first have to be relaxed, allowing various services to operate in various parts of the frequency spectrum.

Licensing

The way in which equipment is licensed would have to be reconsidered, given that a device would have the capability to operate as many different types of devices. Furthermore, the ability to add extra services or to modify an SDR after it has been deployed would not be in accordance with current type certification or licensing models. New licensing regimes will need increased flexibility to accommodate SDR.

FCC[46]

The FCC issued two notices for public consultation last year on the "Authorisation and Use of Software Defined Radios". First a NOI (Notice of Inquiry) in March, followed up by an NPRM (Notice of Proposed Rule Making) in December[47]. The FCC argues that, at this stage, new combinations of hardware and software cannot be authorised without individual testing and certification, since the radio emissions cannot be simulated or predicted adequately. The FCC has proposed to permit changes to SDR equipment by modifying their authorisation procedure. This new streamlined authorisation procedure would require applicants to submit test data showing the compliance of any software or hardware configuration changes to a certified device. The applicant would then be notified of the authorisation, before any new software can be downloaded to equipment in the field, and a re-labelling of equipment will not be required[48]. At this stage it is not clear if the FCC will implement these changes.

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[46] Federal Communications Commission of the United States of America.

[47] FCC, NOI & NPRM, "On Authorisation and Use of Software Defined Radios", March 2000, December 2000, ET Docket No. 00-47.

[48] The FCC suggests that equipment labels could be displayed on LCDs or LED displays allowing them to be changed to reflect any reconfigurations.

Cognitive Radio

Looking further ahead, and extending this idea of programmable radio further brings about the concept of cognitive radio [Mitola, 1999]. A cognitive radio makes observations of radio usage in its surrounding environment before transmission and, using other previously obtained or programmed knowledge (e.g. frequency allocations, geographical location, availability and price of services), chooses how to provide a particular communications service. All this would occur within a fraction of a second unbeknownst to the user. Cognitive radio is still at the research stage and would not be expected to become commercial for 5 to 10 years.

3.5.5 Implementation Issues

An SDR is implemented through the use of generic software modules running on top of a set of non vendor specific hardware devices.

A key issue in the implementation of an SDR is its level of programmability, which is dependent to a large extent on how much of a device is implemented with digital technology[49]. The more digital a radio is (i.e. the closer to the antenna that analogue to digital and digital to analogue conversion occurs) the more potential there is for programmability[50]. The difficulty with implementing a more digital and programmable radio is in the limitations of certain hardware elements (see table below).

Key Hardware Elements	Description	Limitations	Developments Needed
Antennas[51]	Converts electrical RF signals to electromagnetic waves.	Physical limitation of antenna size – size is directly related to frequency of operation.	Broadband antennas. Adaptive antenna arrays.
RF conversion and IF (Intermediate Frequency) processing	Amplify in-coming and out-going signals. Convert frequencies.	Wideband amplification and wideband up/down converters needed.	Advances in semi-conductor and super-conductor technology.
Analogue to Digital Converters (ADC), Digital to Analogue Converters	Convert between analogue and digital signals.	High speed (sample rate) high resolution devices needed.	Advances in semi-conductor and super-conductor technology.

[49] The SDR Forum defines 5 tiers of radio: Hardware Radio, Software Controlled Radio, Software Defined Radio, Ideal Software Radio and Ultimate Software Radio or Software Radio, each with increased levels of programmability and flexibility.

[50] It is important to distinguish between a digital radio (which may not be programmable) and a Software Defined Radio (which is programmable).

[51] The physical limitations of antennas will ultimately limit the capabilities of SDR technology.

(DAC)			
Digital Signal Processing (DSP)	General purpose processors.	High speed, low power, highly programmable devices needed.	Advances in semi-conductor technology and architecture.

3.5.6 Potential Problems

Security

As radio networks become more defined by software configuration than by hardware implementation it can be expected that the radio world would experience similar security threats to those experienced in the IT world (e.g. from viruses, hackers and internal security breaches). It is conceivable that if a radio network is re-configurable through software it is also vulnerable to attack through this software. Work being carried out by ETSI and the SDR Forum on standardisation of secure wireless authorisation protocols should help protect future systems from such security threats.

Authorisation

A problem with the possibility of multiple SDR configurations is that control of unauthorised configurations is difficult and complicated. The SDR Forum is promoting open standards that include some form of authorisation procedure for SDR use, ensuring that radios may only access spectrum once a particular mode of operation has been authorised.

3.5.7 Conclusion

Software defined radio has the potential to fundamentally transform the delivery of radiocommunications services. If implemented correctly, it could eventually enable the responsibility of spectrum management to be handed over to network management software, avoiding interference problems before they arise. International roaming and interoperability would become seamless and transparent and consumers would be afforded a greater choice of service. However, if implemented without due caution, SDR could lead to increased interference levels and spectrum abuse.

Time Frame

Much technological advancement is still needed (e.g. DSPs, ADCs) before some of the advantages mentioned above can be fully realised. Although the transition from current radio technologies to software defined technologies will be gradual, there is already some evidence of moves towards SDR. For instance, some cellular base stations already employ SDR technology to implement multi-band systems (e.g. GSM900 & GSM1800). Prototype SDR systems have been demonstrated by the military since the 90's and most major equipment manufactures have also demonstrated such devices in some form. Military and aeronautical applications potentially represent niche SDR markets.

It is reasonable to expect that early 3G handsets, particularly where multi-mode operation is required (i.e. UMTS & GPRS), will utilise a certain level of SDR technology. This is also the market that is most likely to drive the technology and lead to eventual mass market adoption. The SDR Forum predicts that most radio manufacturers will have adopted SDR as their core platform by 2005[52].

Irish Implications

SDR can potentially deliver increased choice to the Irish market, offering more flexibility of service to consumers and service providers. It would also mean that operators and users would generally be less vulnerable to technology obsolescence.

A key benefit of SDR is that manufacturers would be able to produce radio terminals for programming by third party software developers. This may present a significant opportunity for the software development industry in Ireland.

3.5.8 Bibliography/References

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Capt. M. Gudaitis et al., *"Tactical Software Radio Concept",* Rome Laboratory/C3BB, New York, IEEE, 1997

Joseph Mitola III *"Cognitive Radio for Flexible Mobile Multimedia Communications",* 6th International Workshop on Mobile Multimedia Communications, Nov. 1999.

Joseph Mitola III *"Software Defined Radio – Object-Orientated Approaches to Wireless Systems Engineering",* Wiley-Interscience, 2000

Software Defined Radio Forum: www.mmitsforum.org

[52] The decision by manufacturers to switch to SDR core platforms may be based more on market strategy than on technology availability (i.e. SDR technology may become available and not adopted).

ITU Study Group 8-1, INFO/25-E, Jersey, Channel Islands, 1998

4 Annex A - Technical options for broadband access

Below is a summary of the major current broadband access technologies.

4.1.1 Optical Fibre

Optical fibre has the most to offer in terms of broadband capacity[53] (and in turn the variation and number of services that can be provided) and reliability. Optical fibre systems work by transmitting signals carrying information through glass fibre cables (i.e. optical fibres) using lasers or light emitting diodes (LEDs). The principal drawback is the cost associated with physically laying cable including the associated civil engineering tasks. The time needed to obtain permission and to complete civil works is also an important consideration here. Fibre optic cables do not require individual licensing, but are normally deployed in the context of a telecommunications network for which licensing may be required (e.g. a public network).

4.1.2 Terrestrial Microwave

Terrestrial Microwave, or fixed point-to-point or point-to-multipoint links, can facilitate inexpensive and rapid roll-out of telecommunications networks. Radio waves (i.e. electromagnetic waves) are used to carry information through the air from a transmitting antenna at one point to a receiving antenna at another point, or to receiving antennas at multiple points (i.e. point-to-multipoint). Capacities of up to 622Mbit/s are typically achievable for back haul networks. Microwave antenna towers or masts can typically be spaced at 40 – 60 km apart, depending on the layout of the landscape (i.e. in a mountainous region more towers would be needed), operating frequencies and the site availability. At very high microwave frequencies (i.e. in the millimetric wavebands), distances will be very much shorter, e.g., 10km or less. Terrestrial microwave radio can be vulnerable to extreme weather conditions and interference problems but with good frequency planning and network design such problems can be overcome. Fixed terrestrial links must be licensed for spectrum management purposes. Currently in Ireland the most significant delays are site acquisition and obtaining planning permission.

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[53] In terms of capacity fibre networks are typically capable of carrying between 2.5 and 80 Giga bits per second (i.e. 80,000 million bits per second) on a fibre pair. New technology developments are continuing to increase fibre capacities.

Terrestrial microwave links require individual licensing[54] in addition to any telecommunications service licensing associated with the network.

4.1.3 Satellite

Satellite systems can be used as the transmission medium for broadband infrastructure, but are more suited to either the provision of telecommunications access, or as international gateways. Radio waves carrying information are transmitted from a satellite earth station (i.e. a satellite dish) to a satellite orbiting in space[55], which then passes the information (using a similar radio link) back down to a receiving earth station, thereby facilitating communication between two points on the earth. Satellite systems can be configured to offer broadband infrastructure requirements, but are typically limited to the lower end of the scale (i.e. up to 155Mbit/s). Broadband satellite access systems (VSATs) typically offer asymmetrical capacities of approximately 2Mbit/s in the downlink (to the customer) and up to a few hundred kbit/s in the uplink direction.

A major physical limitation[56] with these systems is the quarter second delay that is added to all transactions which degrades real time interactive applications such as video conferencing, voice communications or other applications dependent on real-time data. Lengthy international co-ordination processes (typically 6 months for an earth station) are often required prior to licensing and such procedures could potentially delay the introduction of services. Most VSAT systems however do not require international co-ordination.

4.1.4 Fixed Wireless Access

Fixed Wireless Access (FWA) is suitable for rapid roll out of broadband access with solutions that meet the demands of small residential users and SMEs. FWA can provide access to telecommunications services (i.e. connect telecommunications service providers to customers' premises) using similar methods to terrestrial microwave (see above). FWA can be used to deliver broadband services in areas where cable is not yet

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[54] See www.odtr.ie document 98/14R.

[55] Typically these are geostationary satellites orbiting 36,000km above the equator which maintain their positions relative to a point on the Earth's surface.

[56] The long distance to and from geostationary satellites imposes a noticeable delay on telephone conversations (a total of half a second). Other non-geostationary satellite systems, which are much nearer to the earth overcome this problem, but broadband services of this type are not expected to be available until 2004 at the earliest.

available such as outlying rural areas. Drawbacks with this technology include site acquisition problems and delays in obtaining planning permission.

FWA links operate in frequency bands shared with other services and use relatively high transmit powers. Therefore in Ireland it is necessary to licence FWA services under the 1926 Wireless Telegraphy Act[57] for spectrum management purposes in addition to a telecommunications service license associated with the network.

4.1.5 Cable/Microwave Multipoint Distribution Service

Cable and Microwave Multipoint Distribution Service (MMDS) access solutions are suitable for home users of broadband services (mainly in the downstream direction). Cable in this context normally means coaxial cable[58], which is connected from the service provider to multiple users in a ‘chain’ arrangement, but can also include fibre optic segments (see fibre section above). Such networks were designed for television broadcasting (i.e. high capacity one way service). Return channels can be available to cable users connected to well designed cable networks, but currently the available capacity would not typically be sufficient for business users.

MMDS operates in a broadly similar way to radio broadcast television systems in that radio signals are transmitted (broadcast) to multiple users. However, there is no MMDS return mechanism as these systems were not originally designed for this purpose (i.e. the radio equipment does not enable this) and return paths have to be provided using different methods (e.g. PSTN, FWA). Cable and MMDS systems require licensing.

4.1.6 Digital Subscriber Line

Digital Subscriber Line (xDSL) technologies are used primarily to provide broadband access services over existing copper cable systems (i.e. existing telephone lines). Equipment is placed on the copper line which enhances its capability to carry information between users and service providers. With ADSL (asymmetric digital subscriber line) capacities of up to 8Mbit/s in the downstream direction (to the customer) and 640kbps upstream are achievable. Other variations such as VDSL can potentially offer up to 50Mbit/s in the downstream direction. xDSL technologies are limited in

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[57] Wireless Telegraphy (Fixed Wireless Point to Multi-point Access Licence) Regulations, 1999. Statutory Instrument No. 287 of 1999.

[58] Coaxial cable is a type of wire consisting of a centre wire surrounded by insulation and a grounded shield of braided wire. The shield minimises electrical and radio frequency interference.

range (distance to customer) and capacity by the quality of installed cable systems. Due to the high data rates involved and the nature of the cable structures spurious radio frequency emissions, which may interfere with existing radiocommunications, may also be a matter of concern.

xDSL links that form part of a telecommunications network may require telecommunications service licensing.

4.1.7 Optical Wireless

Optical wireless technology or free-space optics is a technology that facilitates broadband communication through the atmosphere using optical signals generated by Light Emitting Diodes (LEDs) or lasers. See Briefing Note 1 of this collection: Optical Wireless Technology.