Commission for
Communications Regulation

Briefing Note Series

Developments in ICT Networking Technology – Compendium of Briefing Notes

Peer to Peer Networking

Ad-hoc and Mesh Networks

Wireless Metropolitan Area Networks

Developments in Wireless Link Technology

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1 Foreword by the Chairperson

This collection of four Briefing Notes has been prepared following on from the first meeting, in May, of the ComReg 'Forward-looking Programme Steering Panel'[1] , which is chaired by Commissioner Isolde Goggin. The topics covered here emerged from that meeting as key technological issues that could potentially have significant impacts on the development of the Irish telecommunications market.

Alternative access to high capacity services is a key theme running through this collection of briefing notes. Emerging wireless technologies such as ad-hoc, mesh and metropolitan area networks can provide alternatives to traditional fixed and wireless services. New wireless link technology can provide much needed lower cost alternatives to traditional microwave radio and leased lines for connecting local access networks to core networks. With the wider availability of high capacity access, end users could use the Internet to harness the resources of other users. Peer to peer services and applications can give users alternative access, where permitted, to other peoples computers, and the information stored on them.

In many cases the technologies described in these briefing notes present opportunities for smaller or new network operators to roll-out services quickly, as well as offering existing operators an opportunity to serve their customers in different and possibly more cost-effective ways. For example new technologies in the field of wireless metropolitan area networks could be used to roll-out high capacity access to end users economically. Other technologies such as ad-hoc networks can be used to form networks between individuals without the need for any prior telecommunications infrastructure such as base stations and masts. Opportunities are also there for co-operative groups to form networks and provide themselves with the communications services that they need.

One of the key drivers for these alternative solutions is the increasing call for widespread broadband access. Technological innovations and the increasing availability and utilisation of un-regulated segments of radio spectrum are also helping to drive the deployment of some of these technologies. The addition of alternative networking technologies alongside existing networks can only help to increase the choice of communications services available to end users in Ireland. In outlining some of these technologies we hope to help inform and stimulate end users and network operators – existing and potential – to give consideration to some of the many new possibilities that are emerging.

Etain Doyle,
Chairperson

[1] The Steering Panel consists of a small group of senior external experts, serving in their individual capacity, from Ireland and overseas who have agreed to advise and assist ComReg on its Forward-looking Programme. See Annex 1 for a list of the panel members. The group highlights and discusses future technology developments and related issues that could impact the development of the Irish telecommunications market. The Programme typically looks two to six years ahead. Its purpose is to help ComReg anticipate technological trends and developments in order that these can be taken into account in shaping ComReg's strategy and its future overall work programme.

2 Comments on this Briefing Note

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

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to arrive on or before Friday 17th October, 2003.

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

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3 Executive Summary

This compendium is published as part of the Briefing Note Series, under ComReg's Forward-looking Programme. The purpose of these notes is to help draw attention to and explain some of the developing technologies that could affect telecommunications in Ireland. This collection of Briefing Notes focuses on the use of 'alternative technologies', and how they can provide end users with a greater choice of telecommunications services. The topics of the Briefing Notes are related and complement one another in various ways which is why they are being grouped together in a compendium. Briefing Notes are primarily aimed at non-technical readers with some background knowledge of telecommunications.

The first of the Briefing Notes is on the topic of 'Peer to Peer (P2P)' networking applications. Most Internet users currently access information that is stored on large centralised server computers, whereas P2P applications enable users to access information stored on other individual users' computers. P2P is a powerful tool that is capable of accessing resources such as content (e.g. music, video, data), computing power (e.g. high speed processors, storage space), and human expertise (e.g. through bulletin board applications) across the Internet. P2P applications have implications for end users, network operators, service providers and content developers. For end users it can mean direct access to content and resources on millions of other end users' computers worldwide. For network operators these applications can greatly increase the levels of traffic on their networks (e.g. up to 70% of some ISPs' traffic is P2P – see Section 4.3.1) with users transferring large data files. Furthermore, the increasing availability of broadband access helps to encourage high capacity usage. On the other hand network service providers could potentially find themselves by-passed to some extent as users turn to one another for services and content. Currently key issues arising from P2P are copyright protection and digital rights management, as content developers (e.g. record companies, film studios) seek to protect their businesses from piracy on the Internet[2].

The second Briefing Note looks at alternative technology in terms of the physical transmission of data. Ad-hoc and Mesh networking technologies can provide alternative techniques to deliver communications services. Ad-hoc wireless networks are formed by individual end user devices (e.g. phones, laptops) connecting directly with one another, without the need for existing wireless infrastructure such as base stations and masts. This approach to wireless networking has already been implemented with standards such as Bluetooth and IEEE 802.11 (Wireless LAN), typically involving short range connections. Other more advanced technologies such as IEEE 802.15.3 and IEEE 802.15.4 (ZigBee) are currently under development. The term ad-hoc networking is also sometimes used to describe networks, formed by co-operative groups, where new users and segments of a network can be added on an ad-hoc basis. Mesh networking techniques can be used both by wireless and fixed line operators. Using this technology wireless operators can install networks that are more flexible and fault tolerant than traditional networks, and can accommodate users without the need for a direct line of sight to a centralised base-station. Mesh networking techniques can also be applied in optical fibre networks to increase resilience, flexibility and efficiency.

[2] These issues fall outside the scope of ComReg's powers (see Section 4.4).

Wireless Metropolitan Area Networks (MAN) is the third topic in this compendium. MANs are networks that deliver communications services in and around an urban area. These networks are typically optical fibre or wireless based. The optical fibre MANs are typically implemented to serve as backhaul, bringing aggregated traffic from local access networks to the national core network infrastructure (i.e. these networks perform a similar function to ring-roads around a town or city). However, the main focus of this Briefing Note is on *wireless* MANs. Wireless MANs are wireless access networks capable of delivering services to end users. This type of technology is becoming increasingly important in the roll-out of broadband access. Some of the technologies here overlap with those described in the Ad-hoc and Mesh networking Briefing Note and in the Wireless Link Technology Briefing Note outlined below.

The final Briefing Note in this collection is on the topic of Wireless Link Technology. This note describes some developments in lower cost alternative solutions for high capacity backhauling of traffic over short distances (up to a few km), where optical fibre or point to point microwave links are traditionally used. New developments in millimetre wave technology (i.e. operating in the region of 60GHz) have given rise to a number of new products. In some cases this technology is packaged in conjunction with optical wireless technology[3]. The radio propagation characteristics at such high frequencies make the operation of these technologies on a licence exempt basis, without a need for frequency planning, more practical in some cases, and many of the current products have been developed to operate in this way.

[3] This is done so that each technology can make up for the shortcomings of the other (e.g. when used in conjunction with optical wireless, radio is intended to provide service during fog and optical wireless could provide service during rain)

4 Peer to Peer Networking

4.1 Introduction

Peer to peer (P2P) technology and applications enable consumers of telecommunication services to share information directly with one another instead of via centralised servers, as in the traditional 'client – server' model (see Fig. 4.1). This could potentially have a significant impact on the way in which we use communications services and applications. With the client-server model information is stored on centralised computers (i.e. servers) which are accessed by end users' computers (i.e. clients) such as PCs used in homes and offices. With the P2P model information is stored in end users' computers (i.e. not on centralised server computers) which have access to one another[4]. The P2P model takes advantage of resources located at the edge of the network (i.e. residing with the end users) such as storage space, computing power, information and content, and the people operating those devices[5]. P2P communications allow people to exchange or share and collaborate using the Internet.

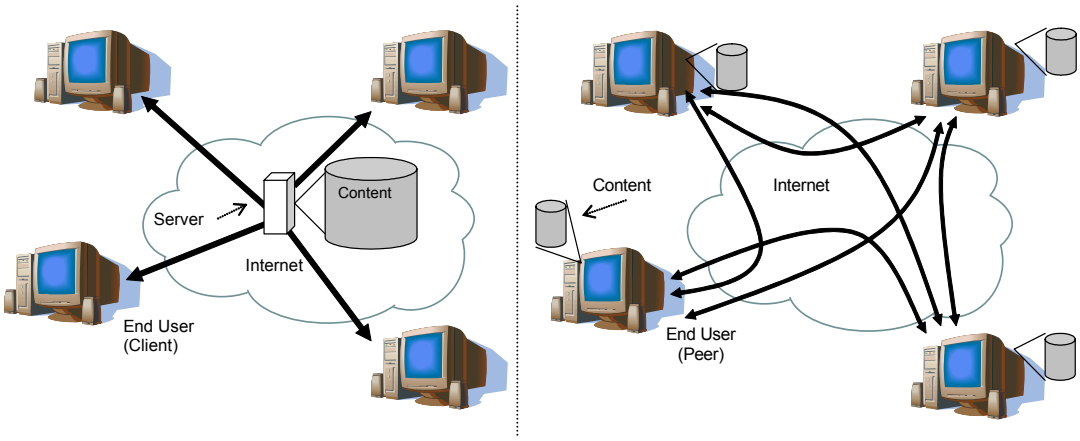

Figure 4.1: (a) Client-Server Model (b) Peer to Peer Model

Recently P2P applications have become more prominent (see Section 4.4), through media sharing networks giving users access to music, video and other content over the Internet.

P2P technology provides an alternative way of using communications services and applications that presents significant opportunities and challenges for network operators and content providers alike. Network operators will need to be ready to adapt to the changing traffic patterns and often increased volumes that P2P applications present. Content providers will need to find new ways to offer their services or to protect their existing means in light of these developments. In many cases operators and content providers will need to develop new business models that take advantage of increasing P2P use.

[4] This is often referred to as a 'distributed' network.

[5] Intel defines P2P as "When your application utilizes resources on other systems that are located at the outer edges of the network, then you are performing P2P computing" - 'Technologies for Sharing and Collaborating on the Net', Intel, November 2002.

For end users P2P applications not only open up access to greater levels of information, storage and computing power, but also enable them to form co-operative communities with other individuals with similar interests. To some extent P2P communications can enable end users to bypass the services of existing telecommunications service providers as they may only require a basic connection to the Internet without any further added value[6].

4.2 Peer to Peer Applications and Technology

P2P applications, broadly speaking, can be separated into the following categories: content sharing, distributed computing and collaboration.

4.2.1 Content Sharing

The most popular P2P application, in terms of the numbers of users and creation of traffic, is content sharing. With this type of P2P users are able to use the Internet to share information and content stored on their computers with other users. This is typically done in exchange for access to information and contents on other users' computers. P2P applications such as 'Kazaa', which has typically over 5 million individual users per week[7], and 'Gnutella' enable users to share various types of content such as audio, video and data files. Another well known P2P application for sharing audio content is Napster, which is currently involved in legal proceedings over copyright issues (see Section 4.4). With increasing levels of broadband access, P2P sharing of video and data files such as software programmes, is likely to become more popular also. P2P communications facilitate Storage Area Networks (SANs) which allow information to be distributed across multiple computers – typically within a single organisation's networks. This can result in both increased redundancy in the event of a failure at one location, and in increased efficiency by locating data nearer to where it is needed.

Search functions in P2P content sharing applications present key technical challenges and given the increasing amounts of content becoming available throughout shared networks, finding relevant material becomes more difficult. Authentication and trust are also important in many situations, particularly where users are only permitted to access content if they make their own content available for sharing. It is important to note that P2P content sharing can involve files of a variety of sizes from text or pictures (a few hundred kBytes) to entire movies (several GBytes). The transfer of such high volumes of data can have significant implications for network dimensions and traffic patterns (see Section 4.3).

A list of common applications for content sharing is given in table 1 below:

Application	Description
BitTorrent	Video
Blubster	Music

[6] Local community based infrastructure can also do this (see Ad-hoc/Mesh Networks Briefing Note – e.g. Irish WAN, the Belfast Beacon) although, not necessarily P2P.

[7] Source – 'RIAA threat may be slowing file swapping', CNET, July 14 2003.

CuteMX	Site offering software for searching and downloading files
FileFury	Search and share software
Filetopia	Messaging and file sharing
Free Network Project	P2P network for information distribution
Gnutella	Search and download system for music, video and other files
Grokster	Music and video, text
Hotline	Messaging, conferencing, file transfer, forming on-line communities
iMesh.com	Direct file transfer
Jungle Monkey	Distributed file sharing programme
Kazaa	P2P software that has been downloaded by over 230 million users for music, video and other files
Morpheus	Shareware using Gnutella
Napster	Music file sharing
OpenNap	Open-source[8] Napster server
Spinfrenzy.com	Music and video sharing
Wrapster v1.0	Music and video

Table 1. P2P programmes and web sites.

4.2.2 Distributed Computing and Grid Computing

P2P communications can enable users to harness the collective computing power of multiple computers connected to a network such as the Internet. This makes it possible to solve complex computing problems over far shorter time-frames than would normally be the case. Although the terms are often interchanged, distributed computing refers to using multiple different computers to solve a problem with different input variables, whereas grid computing refers to dividing a complex problem into smaller segments for solution on different computers. An example of grid computing is the 'SETI @ home' project which made use of the unused processing power on millions of PCs to analyse astronomical data[9]. Distributed computing is currently being used to solve a variety of complex problems including some in the medical field. For example the Screensaver Lifesaver project uses idle power on over two million PCs to search for cancer fighting properties among a large number of molecules[10].

Grid computing is also sometimes known as utility computing, or computing on demand. Grid computing can be used to reduce the cost of ownership of IT resources for the scientific research community and organisations often with large complex problems to solve. The ability to convert fixed IT costs into variable costs is an attractive prospect to many businesses and is being targeted by IBM's 'e-business on demand' strategy[11]. This is achieved through outsourcing IT resources

[8] Open-source means that the programme code is freely available for individuals to modify.

[9] www.setiathome.ssl.berkeley.edu - While no direct communication occurs between the individual peers this is an example of grid computing.

[10] http://www.chem.ox.ac.uk/curecancer.html - Project set up by Intel, United Devices, National Centre for Cancer Research and the University of Oxford.

[11] 'More and more about business priorities – less and less about IT', Financial Times, July 16 2003.

such as hardware, computing power and applications allowing users to share computing resources over a telecommunications network as information and content is shared over the Internet.

The concept of grid computing means that individual end users do not necessarily need to be in possession of powerful computing hardware to solve complex problems. Once they have access to communications services they can use grid technology to solve their problems on other more powerful computers located elsewhere. This means that, as far as the end user is concerned, their mobile communications device for example, has the potential to access more powerful computers via communications links in order to carry out complex calculations or simulations.

CERN[12] in Switzerland is planning on making use of grid computing to analyse the billions of Gigabytes of data a year expected from their LHC[13] apparatus when it becomes operational in 2007. Grid-Ireland is an Irish grid computing initiative linking universities and research institutes that utilises the HEAnet (Higher Education Authority network)[14].

4.2.3 Collaboration

Collaborative applications are facilitated by P2P communications allowing users to work together in real-time on a single file. The Ford Motor Company is making use of P2P technology from Oculus Technologies to enable Ford designers in geographically dispersed locations to collaborate more effectively in the design process[15]. P2P networks can be utilised to harness human resources in different locations, enabling users to share knowledge and interact with one another.

4.2.4 P2P Technology

For P2P content sharing applications users must utilise P2P software that enables them to request content from other users' computers and to respond to requests from others. Numerous programmes are freely available on the Internet to carry out these tasks (e.g. Gnutella, Kazaa – See Table 1 above). Some P2P systems such as Napster make use of a centralised server to mediate between the P2P end users, maintaining a centralised list of the information stored amongst the P2P members on its network[16]. With increasing amounts of data being stored on P2P networks, P2P search engines could be used to find information that ordinary web search engines cannot reach, thereby greatly extending the range of information available to end users of the Internet. For grid and distributed computing applications resource broker programmes can choose the best places to carry out computation based on various criteria such as availability, speed and price. In which case computing power becomes a commodity.

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[12] CERN – European Centre for Nuclear Research. See also www.globus.org

[13] Large Hadron Collider

[14] http://www.grid-ireland.org/

[15] http://www.oculustech.com/news/ford-010327.html

[16] Source – Intel, *'Technologies for Sharing and Collaborating on the Net',* November 2002.

Developments in compression technologies and the availability of high capacity access are making the transfer of movie files more feasible (see Section 4.3.1).

For P2P communications networks to develop to include ordinary end users their computers need to be easily contactable by other users. Problems can emerge here where dynamic IP addresses[17] are used, because the P2P network may not be able to find a member of its network at any given time (e.g. a user could be located behind a firewall)[18]. The implementation of IPv6 could help with this issue in some cases (see IPv6 Briefing Note[19])[20]. Numerous types of communications architectures, platforms and middleware exist for the different types of P2P without any unified standardisation. XML (eXtensible Mark-up Language) is becoming an important tool to help facilitate P2P communications, and can be used to describe namespaces and names. Through the use of XML technology some level of standardisation could be achieved.

Other key technical issues faced by P2P technology developers are: cross-platform interoperability, security, local autonomy, persistence, scalability, and extensibility. Some of the networking technologies associated with grid computing are related to mesh technologies which are the subject of the next Briefing Note in this compendium.

4.3 Global Market Developments

P2P communications have significant implications for media and content providers, communications network operators and end users of services. P2P technology has also attracted interest from key ICT companies. For example, Intel formed a peer-to-peer developer's forum in 2000. A developer's platform is available from Microsoft for Windows, enabling software developers to create new P2P applications. For many media and content developers P2P technology initially appears as a threat giving end users (i.e. their own customers) a simple way to bypass them in accessing content such as music and video archives. Some claims from the music industry correlate a recent drop in CD sales to the emergence of P2P music sharing

[17] Dynamic IP Addresses are temporary IP addresses that can be assigned to users when they need them (e.g. when they access the Internet). When the user is finished with the IP address (e.g. when they disconnect from the Internet) that same IP address is made available for other users. This allows a limited number of IP addresses to serve a larger number of intermittent users.

[18] The individual peers need to be able to communicate with one another at any given time. On the Internet, the Domain Name System (DNS) is used for naming end users. This system is not adequate for P2P applications where a user may access the Internet from different places at different times (e.g. in the office during the day and at home during the evening). DNS names must be mapped to IP addresses as they change for a user. According to Probe Research ("Voice and Data Networks, the next 10 years"), Napster created 23 million non-DNS addresses in 18 months. Furthermore the total number of P2P addresses equals the total number of DNS addresses.

[19] http://www.comreg.ie/_fileupload/publications/odtr0263.pdf

[20] Note - Readers may wish to refer to the ComReg document 'ENUM: Ireland's Next Steps' on ComReg's recent ENUM initiative - http://www.comreg.ie/_fileupload/publications/ComReg0396.pdf

applications[21]. On the other hand supporters of free sharing of music content claim that P2P file sharing could help increase music sales by affording people the opportunity to explore a greater variety of music i.e. 'try before buy'. Similarly, concerns exist in the movie industry over the potential of P2P technology to bypass traditional distribution methods and revenue streams. The long term significance of these concerns remains unclear.

4.3.1 Increasing Traffic

Nevertheless, the widespread adoption of P2P communications for the transfer of large data files such as video could potentially create substantial amounts of traffic on operators' networks. For network operators this is an important source of demand for broadband access that could encourage them to progress more rapidly with broadband roll-out. The widespread availability of broadband access is also likely to lead to further adoption of P2P technology for file sharing applications[22]. Telecommunications service providers need to take advantage of the increased volumes of traffic being sent over their networks as a result of P2P applications, and they need to develop strategies to avoid losing revenue as P2P usage increases. Since operators make no value added revenues on P2P traffic they need to manage the impact of increasing network traffic levels. Often this is achieved by applying a limit on the amount of data that a user can transfer. One option is to create tiered pricing structures that are matched to different levels of usage. Operators can also optimise their networks for carrying P2P traffic using techniques such as local file caching[23] to help cope with growing trends in P2P usage. However, until the legal implications for carrying P2P traffic are clarified[24] operators may be somewhat reluctant to optimise their networks in this way. As with other communications services it is likely that once they are well established, much of the communications will become localised (e.g. people communicate with the people that they know, who are also the people that they typically live near). It is also likely that P2P communications will develop clear daily traffic patterns with its own associated peak and off-peak times.

4.3.2 Security and Privacy

Other important issues that emerge as a consequence of P2P communications are increased security and privacy. If end users are in more control over the communications services they use, as is the case with P2P systems, they must also be more responsible for protecting themselves against security threats such as viruses. Furthermore the creators of such viruses are likely to take advantage of these

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[21] http://news.bbc.co.uk/1/hi/technology/1841768.stm

[22] According to Jupiter Research over 75% of European broadband subscribers use P2P networks. Source – BBC News Online (http://news.bbc.co.uk/1/hi/technology/2745445.stm)

[23] Caching of files does not necessarily make them more or less available to end users, although it does lessen the load on an operator's network. http://news.com.com/2102-1025_3-1027508.html?tag=ni_print

[24] In the US ISPs are required, under the Digital Millennium Copyright Act, to block access when notified that users are distributing copyright material. Source – Liebowitz, 'Re-Thinking The Network Economy', Amacom 2002, pp. 147.

changing usage patterns thus enabling them to create new threats[25]. Privacy needs to be assured if users are to participate in P2P communities since users are expected to grant other users a certain level of access to their computers, whilst maintaining their separation from their private information. Related issues such as authentication, authorisation and data integrity are also important.

4.3.1 Market Development Implications for Ireland

The factors mentioned above are all relevant to the Irish market. The development and take-up of P2P applications by users could affect the role and influence of Internet Service Providers (ISPs) in Ireland. Operators merely carry this traffic without gaining any value added service related revenue from the end users, thus potentially weakening the link between users and the operator. It has been estimated that up to 70% of some ISPs capacity is utilised by P2P traffic[26]. By seeking out new opportunities from P2P applications and utilising grid computing technology, operators could potentially offer customers' services that could allow them to outsource some of their communications and IT functions. For example automatic call distribution and contact centre functions could be outsourced to telecommunications service providers using grid computing technology[27] (see Section 4.2.2).

4.4 Legal and Regulatory Issues

Copyright protection and digital rights management are key issues for P2P communications. ComReg has no role in the adjudication or settlement of copyright disputes or for that matter in the regulation of content. In Ireland the law relating to copyright is set out in the Copyright and Related Rights Act, 2000 ('the Act of 2000') and the decisions of the Irish courts[28]. P2P technology presents a clear threat to traditional media and content distribution and revenue collection methods and the music industry is currently attempting to stifle the trend for on-line sharing of

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[25] It is however worth noting that P2P technology can be exploited to enhance security features (http://magazine.medill.nwu.edu/bright/brightlite/peer3.html).

[26] Source Ovum: http://www.totaltele.com/interviews/display.asp?InterviewID=228

[27] Source Telephony Online: http://telephonyonline.com/ar/telecom_contact_center_ondemand/

[28] Section 17 (2) of the Act of 2000 sets out what sort of works are protected by copyright:-

'Copyright subsists, in accordance with this Act, in-

(a) original literary, dramatic, musical or artistic works,

(b) sound recordings, films, broadcasts or cable programmes,

(c) the typographical arrangement of published editions, and

(d) original databases.'

Where there is a dispute in relation to copyright, either as a result of an alleged breach of the Act of 2000 (such as an infringement of copyright) or as a result of an alleged breach of contract, the matter would normally be brought before the Irish Courts, unless as a matter of contract the parties in dispute had provided for arbitration. The Court has available to it a range of remedies in respect of a party alleging a breach of copyright or related rights or a party alleging a breach of contract. These remedies include of course the injunction and the power to award damages.

music[29]. The legal situation in relation to P2P sharing of music files is currently under examination in the US courts with the Recording Industry Association of America (RIAA) taking some high profile cases against users of P2P systems[30]. Although eager to optimise their networks for P2P communications, network operators are unsure as to their potential liability in these copyright issues. There is currently ongoing legal action in the US and Europe[31] regarding this issue.

It is worth noting that the software industry, and in particular gaming software, has always had to deal with the illegal copying and sharing of their products. Previously they have adopted strategies that accept some small level of piracy but are now generally moving towards subscription based relationships with their customers (e.g. Microsoft's Software Assurance programme, multiplayer game subscriptions). The software industry is aware that increases in the use of encryption and complex authentication procedures can irritate customers.

An underlying regulatory implication of the use of P2P technology is that its use in the distribution of traditional broadcast material over the Internet could potentially impact broadcast markets[32].

4.5 Conclusion

Peer to peer communications can expand the value end users can gain from telecommunications services giving them direct access to content, storage, computational power, and other users via the Internet. P2P has already demonstrated its potential appeal with the rapid growth seen in online music sharing applications such as Kazaa – despite the controversy and questions concerning the legal standing of such use.

If 'the network is the computer'[33], then P2P is an application that can harness the power of that unified 'computer'. P2P is a strong emerging force in the ICT industry that is likely to impact the way in which many of us access and value information and content over the Internet and in the way content developers distribute their media. This will give rise to new business models and new commercial

[29] Similar situations existed in the 80s with the introduction of home recordable audio cassettes, and video cassettes. However P2P technology utilising the Internet is potentially a more powerful threat. Source – Stan Liebowitz, *'Re-Thinking the Network Economy',* Amacom, 2002.

[30] The RIAA won a court order forcing Verizon to divulge the names of some of their subscribers which is currently under appeal.

[31] http://news.com.com/2100-1027_3-5058666.html?tag=fd_top

[32] ComReg 03/61 – Future regulation of electronic communications networks and services – arrangements for general authorisations (Consultation paper) – section 5.3.2

[33] 'The network is the computer' is a registered trade mark of SUN Microsystems Inc.

opportunities, as well as putting at risk some existing ones. P2P applications are bringing about a large increase in the amount of data people communicate to one another creating further demand for access to high capacity communications networks. Similarly the availability of high capacity broadband access networks is likely to encourage the growth of P2P usage even further. Communications network operators may need to consider how best to optimise their networks and tariff schemes to maximise their efficiency for P2P communications. Although there are legal uncertainties surrounding P2P content sharing, these are likely to be resolved in time. Other aspects of P2P such as grid and distributed computing are already having a significant effect on the utility of computers and the Internet.

5 Ad-hoc and Mesh Networks

5.1 Introduction

New ad-hoc and mesh network architectures are now emerging which are fundamentally different from the majority of current telecommunications networks in the way in which they can be created and how they operate. The term 'ad-hoc network' can refer to two different aspects of telecommunications systems. First, a network's physical operation can be implemented in an ad-hoc manner. In this case individual devices (e.g. handsets, roof-top terminals) communicate directly with one another, without any prior design or planning, and without the need for any existing physical infrastructure such as towers, cables, switches and routers (Fig. 5.1). Secondly, the term 'ad-hoc' can be used to describe the commercial structure of a network. Such networks are typically formed by not-for-profit, co-operative or community groups, in which new members or sections can be added to the network in an ad-hoc manner without a prior roll-out plan. Of key importance here is that these networks can provide their own physical infrastructure relying less, if at all, on traditional commercial network operators[34].

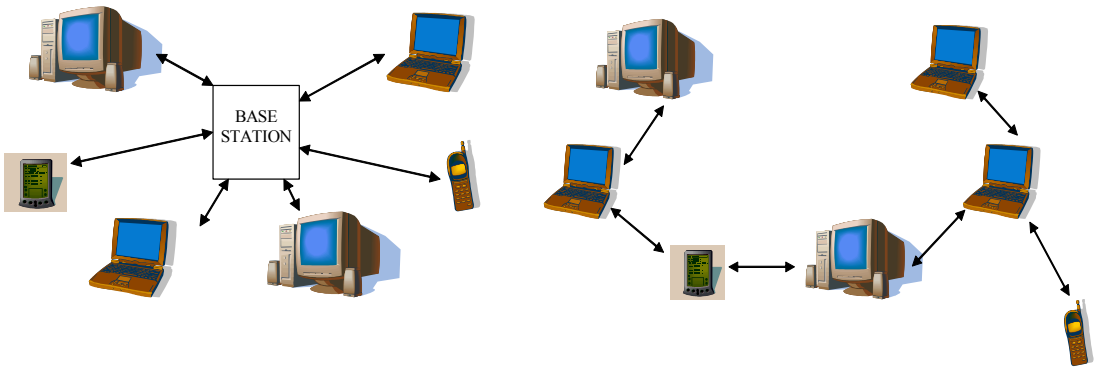

Figure 5.1: (a) Traditional Network (b) Ad-hoc Network

Figure 5.1 above shows a comparison of a traditional centralised cellular network (Fig. 5.1(a)) with a distributed ad-hoc network (Fig. 5.1(b)). With the ad-hoc network no existing infrastructure such as base stations is needed – devices communicate directly with one another (unlike in Fig. 5.1(a) where devices must communicate via a central base station). In an ad-hoc network each device is capable of relaying information from other users allowing them to communicate across the network. In Fig. 5.1(b) it can be seen that the range of an ad-hoc network can potentially exceed that of a more traditional network by utilising the ability of terminals to relay information.

Some of the early builders and users of ad-hoc networks (in the commercial sense) include frustrated user groups seeking communications services in areas with limited infrastructure. These have often been set up as not-for-profit activities which can lead to communications services becoming available at lower than normal commercial rates. This type of technology allows for a 'bottom up' approach to network roll-out where network infrastructure only exists by virtue of the users connected.

[34] A relationship must be formed with a service provider in cases where access to the Internet or interconnection to other networks is required.

In many cases these ad-hoc networks, in the physical sense, can also be described as mesh networks in that users can be directly connected to multiple other users, instead of just one or two as a link in a chain (Figure 5.2). When dealing with mobile terminals it is important that individual terminals (i.e. users' devices) can dynamically change their relative connections within the network (e.g. to connect to the nearest other terminal). This type of mesh and ad-hoc technology has been developed for short range mobile applications (e.g. Bluetooth, ZigBee, WLAN – see Section 5.2). More advanced developments could help adapt this technology for wider area mobile use.

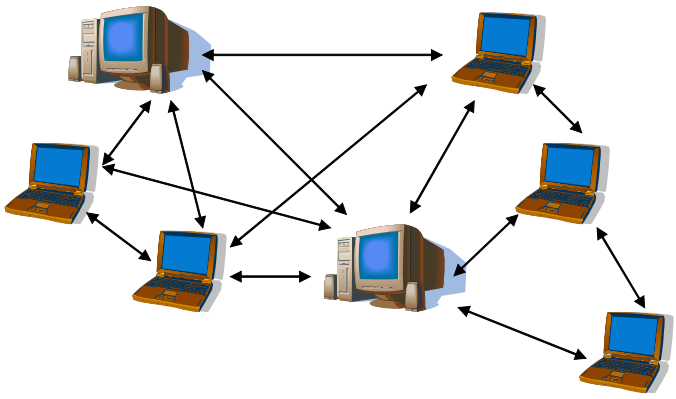

Figure 5.2: Mesh Network

Mesh networks are often also formed in a fixed (not ad-hoc) manner[35]. In this case mesh networking techniques can be applied to larger optical networks linking each point on the network directly with multiple other points. A large telecommunications operator with national optical infrastructure might apply this technology for example. Similarly a fixed wireless access provider could apply this technology to increase their network reach as they add new customers without first rolling out more base stations. In this case each device can potentially act as a repeater station, allowing other users to transparently access services on the provider's network through these devices. The purpose of this is to increase flexibility in traffic management and to increase redundancy for more resilience. Network designers attempting to maximise efficiency of their network must strike a balance between network flexibility (i.e. using more links in a tighter mesh), and network cost.

5.2 Technologies

Ad-hoc and mesh networks are mostly associated with wireless technologies and these are the main focus of this Briefing Note. Optical fibre mesh technology is also briefly included here. Although some technologies that support ad-hoc networking are already available, some more advanced ad-hoc networking technologies are the subject of advanced research and development[36]. Some of the main ad-hoc and mesh technologies are outlined below.

[35] This type of network can also be described as a multi-point to multi-point network.

[36] See http://w3.antd.nist.gov/wctg/manet/ADHOC for a list of links to ad-hoc networking related websites.

5.2.1 Wireless Local Area Networks

WLAN technology is widely available at affordable prices (see WLAN briefing note[37]) and devices can be used as building blocks to create small (i.e. local area) to medium sized (using links of several kilometres) ad-hoc networks. This technology is typically used to provide portable or nomadic wireless access to users, and to build private networks (e.g. in office, in a town). IEEE 802.11 wireless technology – also known as Wi-Fi – is capable of forming ad-hoc network connections. In this case individual user terminals (e.g. laptop/handheld computers) can connect directly to one another if out of range of a base station (i.e. access point). This is known as a multi-hop ad-hoc network since the outermost terminals must communicate with the serving access point via another terminal which merely relays the information. IEEE 802.11 technology operates in licence exempt spectrum in the 2.4GHz and 5GHz bands[38].

5.2.2 Bluetooth

Bluetooth was developed as a short range cable replacement technology that can operate on an ad-hoc basis. This technology is typically used to connect users' devices to one another (e.g. a mobile handset to a computer or a fixed line phone[39]) or to other users located in close proximity. Bluetooth devices organise themselves into clusters or groups known as 'piconets' of up to 8 devices of which one is in control (i.e. 'master'). Two piconets can be connected together expanding the size of the network. This is known as 'scatternet' and is facilitated through a single device which operates in both piconets. The number of devices that can effectively operate within a given area is limited by spectrum availability, since each device requires some spectrum resources. In a Bluetooth network devices can join and leave the network as appropriate. Bluetooth operates in licence exempt spectrum in the 2.4GHz band[40]. Bluetooth was developed by the Bluetooth Special Interests Group (SIG), which was formed in 1998 by companies including Ericsson, Intel, IBM, Toshiba, and Nokia. Bluetooth has also been standardised by the IEEE under the 802.15.1 standard[41].

5.2.3 ZigBee

ZigBee, is an emerging standard for low power, low data rate wireless networks. These networks are typically used to inter-connect sensors or telemetry devices which can be deployed on an ad-hoc basis (e.g. in a manufacturing plant, wearable medical sensors, 'smart' badges) – see Section 5.3. Intel, Motorola and Philips are among the companies working on ZigBee technology[42]. This technology operates in

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[37] www.comreg.ie/_fileupload/publications/odtr0216.pdf

[38] In Europe this equipment must comply with the relevant ETSI specifications.

[39] BT's Bluephone service will use Bluetooth technology allowing users to avail of lower cost fixed line call charges from their Bluetooth equipped mobile phones while at home.

[40] In Europe this equipment must comply with the relevant ETSI specifications.

[41] IEEE 802.15.1 is equivalent to Bluetooth version 1.1 and IEEE 802.15.1a is equivalent to Bluetooth version 1.2.

[42] www.zigbee.org

the 2.4GHz spectrum (and at 868MHz). ZigBee technology is designed to be very power efficient and can operate for several months or even years on a single battery charge. ZigBee relies on the IEEE 802.15.4 standard[43] and can be operated within the license exempt regulatory framework in Ireland.

5.2.4 IEEE 802.15.3[44] and Ultra Wide Band

The IEEE 802.15.3 standards are for personal area networks (PANs) typically operating over short ranges (i.e. less than 10 metres) – see Section 5.3. Ultra-Wide Band (UWB) technologies are proposed for 802.15.3. UWB utilises extremely large bands of spectrum (i.e. greater than 500MHz) at very low powers (see UWB Technology Briefing Note[45]). Early UWB deployments are occurring in the US where FCC[46] approved equipment is already available (e.g. Time Domain). Under the FCC regulations many systems are only permitted for indoor application[47], with only hand-held systems permitted for outdoor use. In Europe the compatibility of UWB with existing services is still currently under investigation (ETSI Task Group 31, CEPT SE24). ComReg is continuing to monitor the progress of UWB standardisation.

Standard	Max Data Rate	Typical Range
IEEE 802.11	54Mbit/s	< 100 metres
Bluetooth	1Mbit/s	< 10 metres
ZigBee	250kbit/s	< 30 metres
IEEE 802.15.3	55Mbit/s	< 10 metres

Table 5.1 – Comparison of key ad-hoc wireless technologies[48]

5.2.5 Other Ad-hoc Technologies

Other fixed wireless technologies such as point to point wireless links (see Wireless Link Technology Briefing Note) can also be used to form ad-hoc wireless networks in the commercial sense. In this case users could deploy fixed point to point wireless technology to connect themselves to a network.

The IETF Mobile Ad-hoc Networks (MANET) working group is developing Internet Protocol and routing standards for mobile ad-hoc networks[49]. The development of

[43] http://grouper.ieee.org/groups/802/15/pub/TG4.html

[44] http://grouper.ieee.org/groups/802/15/pub/TG3.html

[45] www.comreg.ie/_fileupload/Publications/odtr0159.pdf

[46] Federal Communications Committee (FCC)

[47] The FCC has restricted UWB operation in an attempt to limit the possibility of causing interference to other users.

[48] Source - IEEE Communications Magazine, '*Ultra-Wideband Radio Technology : Potential and Challenges* Ahead', July 2003.

[49] http://www.ietf.org/html.charters/manet-charter.html

routing protocols is a key technical issue for ad-hoc networking technologies. Research into ad-hoc networks is currently underway at Trinity College Dublin[50].

5.2.6 Mesh Networking Technology

There are numerous different systems available that could be described as mesh networks, including some of the ad-hoc networks mentioned above. Some of the mesh networking technologies that are available are proprietary, while others can operate using existing wireless standards and technologies. Some of the key proprietary mesh networking systems are outlined briefly below[51].

- *Mesh Network*'s[52] technology can be applied to various different wireless technologies such as 802.11 and their own QDMA[53] technology. Mesh Network's technology can offer users data rates up to 11Mbit/s (for 802.11) and up to 6Mbit/s (for QDMA). The QDMA technology can be operated at distances up to 1.6km and to mobile users travelling at speeds up to 100 miles per hour. Mesh Network's technology has been deployed in the US by public safety bodies (e.g. Orange County Fire and Rescue) to take advantage of its positioning and location features.

- *Mobile Telecommunications Radio Relay Network* (MOTERAN[54]). This is a software based technology being developed by Mitsubishi and Deutsche Telecom. The software will enable the formation of mesh networks, on an ad-hoc basis, using existing networking technologies. This is currently being developed for WLAN equipment placed on cars to exploit Germany's high density of cars.

- *MeshWorks* from Radiant Networks[55] (Cambridge, UK) employs wireless mesh technology for Fixed Wireless Access solutions in the 5.8GHz and 26/28GHz bands. Radiant Network's technology can provide end users service at up to 8Mbit/s (at 5.8GHz) and up to 25Mbit/s (at 26 or 28GHz). The maximum distance between nodes (i.e. terminals) on a network is 2km.[56] This technology was rolled out to seven buildings in Salem, Virginia (USA) in less than seven days.

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[50] WAND: Wireless Ad-hoc Network for Dublin at the Distributed Systems Group in the Department of Computer Science (www.dsg.cs.tcd.ie), and DAWN: Dublin Ad-hoc Wireless Network at the Networks and Telecommunications Research Group (NTRG) (www.ntrg.cs.tcd.ie/dawn.php).

[51] These are just some examples of mesh networking technology and are not intended to be a comprehensive list. ComReg would welcome the submission of further examples by respondents to this Briefing Note.

[52] www.meshnetworks.com

[53] Quadrature Division Multiple Access

[54] www.moteran.com

[55] www.radiantnetworks.com

[56] BT Wholesale began a trial of MeshWorks in South Wales in July 2002 to extend broadband coverage beyond the reach of DSL.

- Mesh networks using optical wireless technology are available from *AirFiber*[57], providing users with data rates up to 622Mbit/s. See also Optical Wireless Technology Briefing Note[58] and the Briefing Note on Wireless Link Technology in this compendium. Airfiber is currently deployed in commercial networks.

- Some other wireless mesh networking companies include Nokia ('*RoofTop*' technology), Sky Pilot Networks[59], Ultra Devices[60], Wave Wireless Networking[61], and Ember[62].

The use of mesh topologies in optical fibre networks can yield increased operational efficiency and flexibility for operators. This involves independently linking up more individual nodes to other nodes in a network instead of connecting them in a traditional ring topology. Typically ring topologies require that 50% of the total capacity be kept in reserve in case a failure occurs. This level of reserve capacity can be reduced using a mesh topology, the extent of which will depend on how many extra links are added. The additional links and alternative routes provided by a mesh network afford an operator more flexibility to provision customers quickly with the capacity that they require (capacity on demand). Optical mesh technology will benefit from the development of optical switching technology[63].

5.3 Applications

Alternative Infrastructure: One of the key applications of ad-hoc technology, as outlined above, is the ability to form communications networks using only users' devices, without having to rely on existing infrastructure or communications service providers. Also, existing network operators could utilise ad-hoc technology to roll-out communications services with a reduction in the initial capital costs associated with traditional network roll-outs. In these cases ad-hoc technology can be used to provide high capacity communications services.

Personal Area Networks: Ad-hoc wireless technology is being deployed (e.g. Bluetooth, IEEE 802.15.4) and is under development (e.g. IEEE 802.15.3) for use in personal area networks. These are short range networks designed to allow devices such as phones, TVs, computers, printers, and other intelligent devices to communicate with one another.

Sensor Networks: Remote devices such as sensors can be networked using ad-hoc technology. These are typically low data rate telemetry applications where low

[57] www.airfiber.com

[58] www.comreg.ie/_fileupload/Publications/odtr0159.pdf

[59] www.skypilot.com

[60] www.ultradevices.com

[61] www.wavewireless.com

[62] www.ember.com

[63] Optical switching enables optical signals to be switched and routed without the need to first convert them back into electrical form.

power operation is important for prolonged battery life. Technologies such as ZigBee (IEEE 802.15.4) are under development for this purpose. Ad-hoc technology could provide low cost easily installable networks of sensors that could be used in many different situations, from safety monitoring of fixed structures such as buildings, to complex machines such as aircraft.

Emergency Situations & Disaster Relief: In emergency situations where existing telecommunications infrastructure has been damaged (e.g. earth quake, hurricane) relief workers can utilise ad-hoc technology to form a communications network very quickly.

Military: Much initial research on ad-hoc technologies was carried out for military purposes. For example ad-hoc networks can be used to provide communications for military forces in cases where they have no telecommunications infrastructure in place or where it has been disabled.

5.4 Market Development Issues for Ireland

Ad-hoc wireless technology can in principle enable users to provide themselves with telecommunications where sufficient infrastructure may not already exist. This has several market development implications for end users and operators of communications networks. For example, in some cases networks created by user groups on an ad-hoc basis could present operators with aggregated traffic that would be more appealing to serve (i.e. a single high capacity link could be used). In other cases this technology could conceivably be used to bypass existing services from network operators (e.g. ISDN, DSL). Advanced mobile ad-hoc networking (MANET) devices could potentially compete with traditional mobile operators.

The ability to roll out this type of technology incrementally makes it suitable to help deliver broadband services in rural areas where traditional technologies may require high initial capital costs. Furthermore the potential accessibility of this technology to co-operative groups (i.e. without the need for advanced spectrum and network planning) could help to overcome the ‘digital divide’ in many areas.

Many initial ad-hoc networking applications are targeted at short range communications such as Personal Area Networks (PANs) connecting devices wirelessly within a couple of metres (i.e. cable replacement technology). While these developments are likely to be significant for the consumer electronics industry, they will increase users’ connectivity and accessibility to communications services thus potentially generating increased traffic levels on communications networks (e.g. a home based wireless network can allow several family members to access the Internet over a single DSL connection).

Communications operators making use of wireless mesh and ad-hoc technologies would have the potential to deliver high capacity services to a greater number of users. For example non line-of-sight mesh networks can reach customers that would be difficult to reach using cellular technology. Mesh and ad-hoc style wireless technologies are also more accessible to new or smaller operators who have limited initial capital to invest, allowing them to mange their network development in a more piecemeal manner meeting the needs of new customers as demand arises.

The widespread availability and adoption of ad-hoc networking technology could alter the balance between centralised controlled networks such as those operated by current telecommunications providers, and de-centralised user controlled networks. This could have overall implications for the size and structure of the telecommunications sector in Ireland and elsewhere.

Despite typically low individual data rates, the widespread application of sensor networks using low cost ad-hoc technology could also potentially create significant aggregate levels of traffic. This has implications for backhaul and core telecommunications networks.

5.5 Regulatory Issues

Most short range technologies operate within licence exempt spectrum and do not need spectrum licences from ComReg, although systems must adhere to certain technical conditions[64]. Some other wireless technologies operate within licensed bands, typically spectrum allocated for fixed wireless access, and must be treated accordingly. Operator-less mobile ad-hoc networks need to operate in licence exempt spectrum which is limited. Before providing networks or services to third parties operators are required to submit a notification to ComReg and are then subject to compliance with standard conditions set out in a general authorisation[65].

Early implementations of wireless ad-hoc technology will typically operate as Short Range Devices (SRDs) in personal area type networks. This will result in there being a potential for private wireless networks to form a publicly available network, through an ad-hoc link, requiring notification to ComReg as described above.

5.6 Conclusion

Ad-hoc networking technology represents a fundamental and major advancement in wireless technology evolution. Such systems make use of intelligence in end users' devices enabling them to form networked communities dynamically with other devices in their proximity without any prior arrangement and without the need for any existing infrastructure such as masts, base stations, cables or switches/exchanges. Ad-hoc wireless technology can make efficient use of available spectrum employing the shortest possible links, and therefore the lowest transmitted powers, between users. The deployment of this type of wireless technology presents opportunities for new or small wireless operators to grow their service as demand arises. Such technology also enables co-operatives to form their own communications networks, thus in some cases reducing dependency on access networks provided by traditional telecommunications operators. It may be attractive for such user groups to utilise this type of technology in areas where there is limited or non-existent coverage from other service providers. Operators offering services to third parties using these technologies are also required to submit a notification to ComReg. In some cases traditional operators would find it attractive to serve the aggregated traffic from an ad-hoc network using a single high capacity connection.

[64] See Permitted Short Range Devices in Ireland - ComReg Doc. 0271: http://www.comreg.ie/_fileupload/publications/odtr0271.pdf

[65] For more details see - http://www.comreg.ie/sector/default.asp?S=4&NavID=195&M=

Mesh technology is sometimes closely related to ad-hoc technology. In wireless access networks mesh technology can be used by fixed wireless access service providers to extend their coverage to non-line of sight locations without adding new base stations or higher masts. It can also provide operators, of both wireless and optical fibre networks, with increased flexibility and redundancy in their networks, thus improving overall reliability and quality of service to end users.

Ad-hoc and mesh networking technologies can provide both significant opportunities and threats to operators of telecommunications networks. Traditional operators will need to adopt these technologies or adapt to operate alongside them. These developments will afford end users greater access to high capacity wireless services with increased mobility and flexibility.

6 Wireless Metropolitan Area Networks (MAN)

6.1 Introduction

A Metropolitan Area Network (MAN) is a telecommunications network that operates within a metropolitan or urban area. The term MAN is typically used to describe two broad categories of network. In one instance a MAN is a high capacity network, typically optical fibre or microwave radio or both, used to transfer traffic around an urban area (see Fig. 6.1(a)). These networks are often formed using 'ring' topologies that interconnect several areas of high traffic aggregation such as business parks. These are the types of MANs being funded by the Department of Communications, Marine and Natural Resources under their 'fibre towns' initiative[66], for example. The other type of MAN typically refers to a fixed wireless access network deployed in an urban area and is known as a wireless MAN (Fig. 6.1(b)). The main focus of this Briefing Note is on recent developments in wireless MANs.

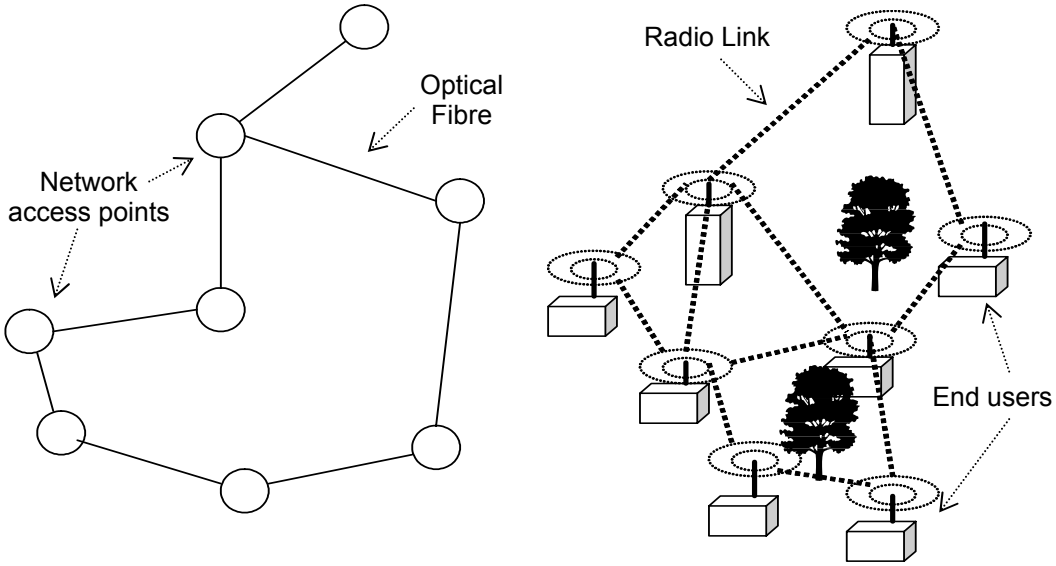

Figure 6.1 (a) Optical Fibre MAN (b) Wireless MAN

Note: In the wireless MAN shown in Fig. 6.1(b) mesh technology is used to circumvent obstructions in the direct line of sight path (e.g. trees).

Wireless MANs are typically used to provide high capacity access to end users and to backhaul communications traffic to the core of the network or to a gateway linking to another operator's network. The potential data rates available from these networks could deliver end users an array of services from voice to high speed data and video services.

6.2 Technology

The two main types of technology used for MANs are optical fibre and wireless. Optical fibre technologies are typically used for back-haul ring type MANs and will only be mentioned briefly here. Recent developments in wireless technologies, including optical wireless or free space optics[67], have created further opportunities

[66] More details can be found on the DCMNR website: www.dcmnr.gov.ie/display.asp/pg=865

[67] See Wireless Link Technology Briefing Note, and www.comreg.ie/_fileupload/Publications/odtr0159.pdf

for fixed wireless access type networks in urban areas (i.e. Wireless MANs). In addition to a number of standardised solutions such as IEEE 802.16 and ETSI HiperMAN there are a number of proprietary products emerging. Currently these types of wireless networks are typically designed to operate in licence exempt radio spectrum or in other fixed wireless access bands such as the 3.5GHz band. Some of the key wireless MAN technologies are briefly outlined below.

6.2.1 IEEE 802.16

IEEE 802.16 is currently the most prominent wireless MAN standard[68]. The 802.16 standard was published in April 2002 and related to the use of 10 to 66GHz spectrum for broadband wireless access. An amendment to the 802.16 standard (i.e. 802.16a) relates specifically to the use of 2 to 11GHz spectrum. This is currently the area of most interest to potential wireless broadband service providers due to the radio propagation characteristics and maturity of wireless hardware in these bands. This standard is capable of data rates up to 70Mbit/s and does not require a direct line of sight between the transmitter and receiver to operate. 802.16c is a further amendment to the standard, aimed at ensuring interoperability between systems operating in the two different frequency ranges. IEEE 802.16 is designed to carry protocols such as ATM, Ethernet and Internet Protocol. Data rates up to 134Mbit/s are possible in each direction in the 10 to 66GHz standard (assuming a 28MHz channel arrangement[69]).

A mobile wireless MAN expert group has also been set up to develop a mobile standard, 802.16e. Continuing on from work carried out by the Mobile Broadband Wireless Access (MBWA) group[70], this expert group is seeking to amend the physical radio and network access aspects of the 802.16 standard to enable combined fixed and mobile operation in licensed bands.

The WiMAX[71] forum is an industry forum that has been set up to help promote and ensure interoperability between IEEE 802.16 and other microwave access technologies, under a single WiMAX standard. This is somewhat similar to the Wi-Fi forum for IEEE 802.11 technology. Major companies such as Intel, Nokia, and Fujitsu are members of the WiMAX forum along with key players in the licence exempt wireless broadband equipment market (e.g. Alvarion[72]).

6.2.2 ETSI HiperMAN

The ETSI HiperMAN (High PERformance Metropolitan Area Network) standard is part of ETSI BRAN (Broadband Radio Access Networks) standardisation project. It is being developed in conjunction with the IEEE 802.16 standard and has adopted the physical radio and network access characteristics of the IEEE standard. This will assist in the harmonisation of equipment and standards. The functional requirements of HiperMAN were published in March 2001. HiperMAN is being developed for

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[68] http://grouper.ieee.org/groups/802/16/index.html

[69] This means that the signal for a single user can occupy 28MHz of spectrum.

[70] http://grouper.ieee.org/groups/802/16/mobile/

[71] Wireless Interoperability for Microwave Access (WiMAX) – www.wimaxforum.org

[72] http://www.alvarion.com

licensed operation in the 2- 11 GHz frequency range and for the 5.8GHz licence exempt band. HiperAccess, a different ETSI BRAN working group, is focusing on the 11 to 66GHz bands. The HiperMAN standard is currently under development.

6.2.3 Wireless LAN

Although designed for local area indoor deployments, wireless local area network (WLAN) technology can often be used effectively to form MAN type networks. IEEE 802.11 technologies (also known as Wi-Fi) are the most widely known form of WLAN technology. WLAN technology operates in radio spectrum in the 2.4GHz and 5GHz bands. In particular IEEE 802.11a operating in the 5GHz frequency band can be deployed in this manner providing end users with data rates up to 54Mbit/s.

Wireless LAN technologies and their potential uses were outlined in our WLAN Briefing Note[73].

6.2.4 Proprietary Technologies

Other proprietary technologies are available or under development. For example innovative broadband wireless technologies from companies such as Navini[74] and Flarion[75] are already being deployed in some parts of the world. Some of the proprietary technologies outlined in the Ad-hoc and Mesh Networks Briefing Note from companies such as Nokia, Radient Networks, and Mesh Networks among others could also be described as wireless MAN technologies.

6.2.5 Overcoming the Limitations of Wireless Systems

Developments in wireless access technologies such as mesh networking (see Ad-hoc and Mesh Networking Briefing Note) and adaptive (i.e. 'smart') antenna systems[76] are helping to overcome some of the limitations of previous wireless access solutions. Enhancements such as these can improve a systems performance in environments that are potentially unfavourable to radio systems (e.g. heavy rain and the presence of other radio systems operating on the same frequencies) thus delivering a greater quality of service to end users.

6.2.6 Metro Ring MANs

Technologies such as optical wireless and the other advanced wireless link technologies (see Wireless Link Technology Briefing Note) can be deployed in conjunction with optical fibre technology. Wireless technology is very useful for linking points on a network where deploying fibre may be prohibitively expensive or not possible. New developments are also occurring in the area of optical fibre ring

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[73] www.comreg.ie/_fileupload/publications/odtr0216.pdf

[74] http://www.navini.com/index.htm - Navini systems are deployed in the US, Korean and the Netherlands among other countries.

[75] http://www.flarion.com/ - Flarion systems are under commercial trials in South Korea.

[76] Adaptive (or 'smart') antenna systems can dynamically direct radio signals to individual users in a particular direction (i.e. choosing the most suitable path), and can similarly reject potential interfering signals coming from a particular direction.

technology, such as Resilient Packet Ring (RPR - IEEE 802.17)[77]. This is designed to increase the efficiency and enhance resilience in optical fibre ring networks. Ethernet is also an important technology standard for optical fibre MANs (Metro Ethernet).

6.3 Market Development Implications for Ireland

Wireless MAN technology can in many cases provide a lower cost alternative for network operators to develop access networks. Provided that there is sufficient radio spectrum in a given area, this can enable new smaller operators, often with strong local interests, to enter the market. Also, the affordability of some wireless MAN technology makes the deployment of networks based on community initiatives more feasible (e.g. The Belfast Beacon project[78] and IrishWAN[79]). New wireless MAN technologies could potentially achieve greater deployment than previous fixed wireless access solutions due to lower equipment costs and improved security and reliability. The emergence of new standards such as IEEE 802.16 is likely to help with development of the wireless MAN and wireless broadband access markets.

In Ireland the Department of Communications, Marine and Natural Resources is funding fibre optic MANs in 19 towns across Ireland under the National Development Plan. End users and network operators will be able to gain high capacity access to these MANs at co-location access points installed around their paths. It is intended that these optical fibre MANs will bring high capacity communications services closer to end users, yielding opportunities for service providers to offer last mile access. The implementation of MAN technology helps to increase overall level of access to broadband services. Aside from the direct benefits of broadband, increased levels of access helps to create greater traffic levels for national backbone network carriers.

6.4 Regulatory Issues

Often the technologies used for wireless MANs operate in licence exempt spectrum, which means that so long as equipment is operated within the required specifications (e.g. power limits) for that band there should be no frequency management issues. Other systems which operate within licensed spectrum require licensing from ComReg[80]. Typically operators of these types of service would seek to operate in spectrum allocated for fixed wireless use (e.g. 3.5GHz). In some instances this spectrum is available for use on a regional/national basis or on a per base-station basis[81]. It is becoming increasingly the case that technological innovations, and new product developments are emerging at a quicker pace than international harmonized standards. Some of these new systems may therefore require additional regulatory

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[77] http://grouper.ieee.org/groups/802/17/

[78] The Belfast Beacon Project is run by the FLAX Trust - http://www.flaxtrust.com/beacon.html

[79] http://www.irishwan.org

[80] Under the Wireless Telegraphy Acts 1926 - 1988

[81] Information concerning the use of licensed spectrum in the 10.5GHz and 26GHz bands can be found at http://www.comreg.ie/_fileupload/publications/ComReg0334.pdf . See http://www.comreg.ie/_fileupload/publications/ComReg0397.pdf for information on the 3.5GHz frequency band.

attention as the standards in place for spectrum management may not be directly applicable.

Operators providing public services using MANs are required to submit a notification to ComReg of their operation[82].

6.5 Conclusion

Metropolitan Area Networks can be used to help provide high capacity communications in urban areas, linking up individual users, industrial parks and access networks. There are two broad categories of MAN. The first category of MAN constructed from optical fibre and is used to carry high capacity backhaul traffic around a metropolitan area, typically in a ring formation. This is the type of MAN being funded under the Department of Communications, Marine and Natural Resources 'fibre towns' initiative. The second category of MAN is a wireless MAN which can be used for similar purposes as the optical fibre MAN but is also for providing access to individual subscribers typically in an urban area.

New technologies and standards are emerging for wireless MANs such as IEEE 802.16 (also known as WiMax) which will offer the prospect of lower cost alternatives for broadband network operators to deliver services. The widespread availability of this type of technology also creates opportunities for co-operative organisations and community groups to provide themselves with broadband access in cases where existing operator's offerings may be inadequate, too expensive, or non-existent.

Wireless MAN systems have been developed to work in both licence exempt spectrum and in licensed spectrum such as the 3.5GHz band. Limitations in the amount of spectrum may ultimately limit the use of such technologies, particularly for high density applications in urban areas.

[82] For more details see - http://www.comreg.ie/sector/default.asp?S=4&NavID=195&M= and http://www.comreg.ie/_fileupload/publications/ComReg0383.pdf

7 Wireless Link Technology

7.1 Introduction

The increasing availability of short range broadband wireless access products are in some cases revealing new bottlenecks in telecommunication infrastructure. In many instances technologies are readily available to provide users with 'broadband' last mile connections, but even with such access they are still unable to avail of high speed services due to low speed or over-crowding on backhaul connections (i.e. the connection from their local exchange or base station to the core network), see Figure 7.1. Technologies available to serve this portion of the network can be expensive to implement e.g. microwave point to point links, optical fibre. This can be particularly prohibitive for smaller operators seeking to build up a network, especially if they are starting out with relatively few customers. A network operator's alternative to installing its own high capacity backhaul links is to lease capacity from another operator. This however can also be expensive for them.

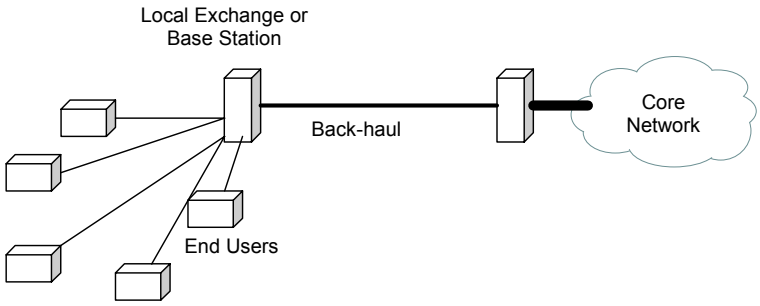

Figure 7.1 – Access network with end users, back-haul, and core network.

This Briefing Note outlines some alternative wireless technologies that are currently available or under development that can potentially offer affordable solutions to this back-haul problem. One currently available alternative for short range links (up to a few km) is Optical Wireless or Free Space Optics which was the subject of an earlier Briefing Note[83]. New developments in microwave radio are also opening up the possibility of lower cost microwave point-to-point links for this purpose. Also, hybrid systems that combine microwave radio with optical wireless or optical fibre might in some cases provide cost effective solutions for network operators. Typically these systems, optical and millimetre wave, operate in licence free radio spectrum. This approach is currently being used in Ireland to successfully provide high capacity wireless back-haul in the 5.8GHz band[84].

7.2 Wireless Link Technology

There are a number of proprietary technologies that make use of microwave radio technology in frequency bands typically above 60GHz. The technologies are often

[83] www.comreg.ie/_fileupload/Publications/odtr0159.pdf

[84] The 5.8GHz band can also be used for fixed wireless access applications such as those described in the Wireless MAN Briefing Note. See also http://www.comreg.ie/_fileupload/publications/ComReg0342.pdf for details of registration of 5.8GHz Wireless access base stations.

known as Millimetre Wave, Upper Millimetre Wave (UMW), or T-rays[85] (see Fig. 7.2).

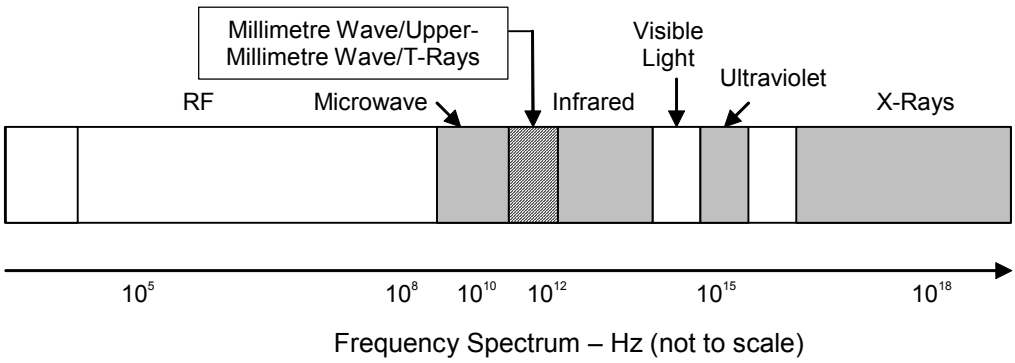

Figure 7.2 – Electromagnetic spectrum

The majority of current microwave radio technologies used for point-to-point links operate at frequencies less than 58 GHz. Traditional microwave radio solutions in lower frequency bands can be limited in spectrum (e.g. usually up to 28 and 56Mhz channels) which typically limits the data capacity available over such links to typically less than 155Mbit/s. Communications technology is only now emerging that can operate at higher frequencies (i.e. in the 60GHz range) where greater amounts of spectrum are potentially available. Systems have been developed to deliver data rates in excess of 1Gbit/s, albeit over shorter distances, in this spectrum. In most cases equipment operating at higher frequencies is more expensive and more difficult to manufacture than equipment operating in lower frequencies. However, new techniques that enable the signals on an optical fibre cable to be converted directly to radio frequency energy in the 60GHz bands can be less expensive than traditional methods (Figure 7.3)[86]. Such techniques allow optical fibre to be directly connected to these links without the need for expensive conversion equipment[87].

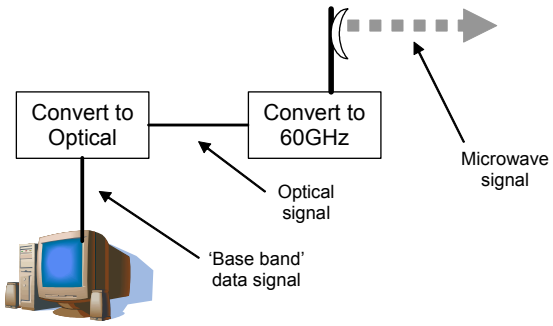

Figure 7.3 – A 60GHz radio system using optical conversion.

[85] T: Terrahertz – 1 Million Mega Hertz.

[86] e.g. techniques such as heterodyning or 'beating' of optical signals can be used to produce RF signals.

[87] Optical/radio hybrid technologies are also developing advanced beam-forming antenna systems (highly focused beams that can be steered without moving the antenna).

Other advances in microwave electronics manufacturing are helping to lower the cost of millimetre wave devices (e.g. Monolithic Microwave Integrated Circuits (MMIC)). One of the main areas where millimetre wave technology is expected to produce cost savings for network operators is in the planning and deployment stage (see Section 7.2.1). With these types of systems links are much more simple to install and do not require the same level of rigorous frequency planning as traditional microwave systems.

7.2.1 Interference

At frequencies of 60GHz and above radio signals emitted from antennas form very narrow focused beams. For example a typical 60GHz system operating over 1km could have only an 80 metre wide signal at the receiver. This property of higher frequency systems greatly reduces the probability of causing or receiving interference from other users. Furthermore, at 60GHz, the particular properties of air cause radio signals to be strongly attenuated. Despite reducing the range over which these systems can operate, this property is actually desirable for short range systems as it reduces the potential for causing interference to other users (i.e. unwanted signals cannot 'stray' too far)[88]. Thus, the narrow beam and strong attenuation properties of millimetre wave systems enhance the ability to re-use frequencies. This means that more of systems can operate in a given area than would otherwise be the case.

Such properties of millimetre radio systems makes them suitable for deployment without the need for detailed spectrum planning and management as in traditional point-to-point microwave frequency bands. These systems are typically designed to operate in licence exempt regulatory environments.

7.2.2 Performance

These millimetre wave systems can suffer degraded performance during wet weather conditions. This is a problem in countries with relatively high levels of rainfall and generally restricts the range over which such systems can operate over. In some cases radio systems are paired with optical wireless equipment to overcome this problem. In cases where rain is inhibiting the use of the radio system the optical wireless link can be used. Similarly, in instances where the optical wireless link may degrade in performance (e.g. due to foggy conditions) the radio frequency link can take over. These hybrid systems can provide the levels of availability[89] that telecommunications operators seek.

7.2.3 Products

Some of the equipment suppliers and their currently available products in this area are listed below:

[88] Research and development is also being carried out on future short range mobile systems in the 60GHz region.

[89] Telecommunications operators and equipment suppliers use the term availability to describe the amount of time that a service can be expected to be operational over a given period (e.g. 99.999% = 5 minutes without service over an entire year).

- *Terabeam's*[90] (formerly Harmonix) GigE and Gigalink systems have obtained FCC certification to operate in the US. These are optical wireless systems paired with a radio over fibre 60GHz solution designed to provide 1Gbit/s in both directions. The Terabeam system can operate from outdoor terminals (e.g. roof top) or from indoor terminals that transmit through windows[91].

- FiberLeap from *Telaxis*[92] is a 60GHz radio system that can deliver up to 2.5Gbps over ranges of up to 1.7km. FiberLeap operates in accordance to FCC rules in unlicensed spectrum.

- *Loea*[93] has developed an innovative system operating in spectrum in the 71 – 76GHz range. This technology can provide data rates up to 1.25Gbit/s over ranges typically up to 1.6km. Distances of up to 13km can be achieved at lower data rates and lower availabilities. Loea's system was used to transmit live high definition TV at the Super Bowl XXXVII from the stadium to ABC's production studio without introducing the normal delays associated with compression technology. However, with the exception of temporary permission granted for individual events, Loea's technology is currently only permitted by the FCC for government use.

- *Nokia* utilised Endwave Corporation's Access 60TM technology for their MetroHopper system. MetroHopper is a 58GHz solution that can be deployed for links ranging between 1-2km at up to 8Mbit/s[94]. This technology has been deployed by Pannon GSM, Hungary, and T-Mobile, Austria.

- *Unique Broadband Systems'* Fiber Connection Series 60GHz Radio can deliver up to 622Mbit/s at ranges of up to 1km[95].

IEEE 802.16 (see Wireless MAN Briefing Note), and other technologies operating primarily in the 5GHz band can also be used to provide cost effective wireless backhaul.

7.3 Market Development Implications for Ireland

A significant barrier to the delivery of high capacity communications services is the availability of low cost backhaul links. Backhaul links are needed to connect broadband access networks to core telecommunications infrastructure and other networks such as the Internet. Low cost, easily installable wireless solutions that do not require advanced radio frequency network planning could create significant opportunities for SME's and co-operative groups to implement broadband access

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[90] http://www.terabeam.com/company/news/releases/20030421.shtml

[91] New World Telecom (Hong Kong) has deployed Gigalink technology. Gigalink links (i.e. both ends) can cost under $10,000.

[92] www.tlxs.com

[93] http://www.loeacommunications.com/

[94] http://www.nokia.com/networks/product_catalog/pc_product_highlights/1,6929,,00.html?prod_id=RAS00008

[95] http://www.uniquesys.com/Connection%20Series.htm#FiberConnection

services (e.g. the Belfast Beacon project using FSona FSO[96]). To some extent, the successful application of 5.8GHz point-to-point links – which could be viewed as a forerunner to millimetre wave technology – is an early indication of the market development potential.

Existing telecommunications operators, including mobile network operators who typically use microwave link technologies in licensed spectrum, could avail of these emerging technologies when rolling out services. 3G network operators could utilise millimetre wave or optical wireless links during the roll-out of their networks. Such technologies would be particularly useful in urban areas where there may be limited availability in traditional microwave frequency bands.

Affordable backhaul is a key requirement for the roll-out of broadband access services. The high capacities afforded by some millimetre wave and optical wireless technologies are capable of handling the aggregated requirements of modern communications users, including the backhaul traffic from ad-hoc and community or co-operative networks (see Ad-hoc and Mesh Networks Briefing Note).

7.4 Regulatory Issues

Microwave point to point links are regulated with clearly defined frequency channel plans already implemented that users must adhere to. It is now becoming the case that radio link technologies are emerging too quickly for traditional standardisation and harmonisation plans leaving individual equipment developers with the task of having to seek approval for the implementation of new technologies.

In many cases millimetre wave links are designed to operate under licence exempt conditions, which greatly simplifies their planning and deployment. In Ireland the band 57.2 to 58.2GHz has been identified as a potential band for unplanned low power use (in accordance with ETSI standard ETS 300408)[97], and could be suitable for license exempt operation. In the US a number of systems have been given authorisation to operate under licence exempt conditions. Other millimetre wave systems such as the Loea system would require very wide bandwidths which are entirely different from traditional point-to-point spectrum allocations (e.g. 900MHz) in frequency bands greater than 70GHz. The Federal Communications Commission began a consultation (Notice of Proposed Rule Making) in June 2002[98] for the use of the 71 to 76GHz, 81 to 86GHz, 92 to 95GHz bands.

Optical wireless technology does not require individual licensing in Ireland since these systems operate at frequencies beyond those specified by the ITU[99] definition of 'radiocommunication' – i.e. greater than 3000 GHz[100].

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[96] Here wireless optical links are used to backhaul traffic from WLAN type access technology - http://www.fsona.com/comp/fSONA_BWB_0303.pdf

[97] See Table of Frequency Allocation Ireland – April 2001: http://www.comreg.ie/_fileupload/publications/odtr0123.pdf

[98] FCC 02-180

[99] International Telecommunications Union – www.itu.int

[100] The ITU is proposing to consider communications systems operating at frequencies greater than 3000GHz – Resolution 118 (The Plenipotentiary Conference of the ITU, Marrakesh, 2002).

7.5 Conclusion

New wireless link technologies operating in new frequency bands have the ability to provide very high capacity communications links, in excess of 2Gbits/s over short distances (~1 km). As well as providing low cost high capacity back-haul alternatives for existing network operators, these technologies create an opportunity for new entrants to develop low cost alternative broadband solutions. Affordable high capacity back-haul technology such as these millimetre wave links could provide a vital backhaul connectivity solution for existing, but as yet under-deployed, broadband access technologies such as WLAN.

Due to the extremely high frequencies involved, this technology is less likely to cause and suffer from radio interference. This could simplify its implementation and may, in some cases, be suitable for licence exempt operation.

Recent technology developments have reduced the cost of millimetre wave technology. Several products based on this are currently available that operate in these bands and in the US early deployments have begun. Combined solutions that utilise both millimetre wave and optical wireless technology can deliver reliable communications, overcoming the drawbacks of each individual technology.

8 Annex 1 – Forward-looking Steering Panel Members

Below is a list of the members of ComReg's Forward-looking Steering Panel.

Eugene O'Leary	Chief Executive	TecNet
Isolde Goggin (Chairperson)	Commissioner	ComReg
John Fagan	Operations Manager	Enterprise Ireland
Michael Donohoe	Head of Emerging Technologies	Eircom
Michael Kelly	Development Executive	TecNet
Mike Carr	Director of Enterprise Venturing	BT Exact
Paul McSweeney	Senior Account Manager	Microsoft Ireland
Philip Hargrave	Chief Scientist	Nortel Networks
Professor Gerard Parr	Chairperson of Telecommunications	University of Ulster
Professor Jim Norton	Independent member	
Tim Kelly	Head of Strategy and Policy	ITU

Other ComReg Members

Gary Healy	Head of Market Development	ComReg
Jonathan Evans	Technology Analyst	ComReg
Patricia Dowling	Information Officer	ComReg
Richard Horton	Senior Programme Manager	ComReg

9 Annex 2 – Regulatory Summary

Table A2 below summarises the developmental and Irish regulatory status of wireless technologies highlighted in this compendium of Briefing Notes.

Technology	Development Status	Deployment to date	Regulatory Status in Ireland
Bluetooth / IEEE 802.15.1	Standard agreed, products available	Widespread deployment, including Ireland	Permitted within licence exempt framework (see A2.2 below)
IEEE 802.11b, g, a	Standards agreed, products available	Widespread deployment of 'b', including Ireland	Permitted within licence exempt framework
Millimetre wave links[101]	Proprietary products available	Limited deployment (e.g. US)	Under review (see A2.1, A2.3 and A2.4 below)
Optical wireless / Free space optics	Proprietary products available	Worldwide deployment, including Ireland	Permitted without licensing
UWB / IEEE 802.15.3	Standard near completion	Limited deployment (test) in US & Singapore	Under review (see A2.1 and A2.2)
WMAN / WiMAX / IEEE 802.16 / HiperMAN	Standard complete, products expected by mid 2004	No commercial deployments to date	Permitted within licensed and license exempt frameworks (e.g. 5.8GHz) (see A2.2 and A2.5)
ZigBee/IEEE 802.15.4	Standard agreed, products expected by end of 2003	No commercial deployments to date	Permitted within licence exempt framework

Table A2 – Regulatory and developmental summary of some wireless systems.

A2.1 Systems Under Review

Many of the wireless systems described in this compendium of Briefing Notes are proprietary systems (e.g. Flarion, Loea, etc.) which in some cases may not be compatible with the types of international standards listed above. Potential applicants seeking to deploy proprietary systems should examine the licensing information given below to verify that such systems comply with the relevant ETSI standards. If the system under considerations falls outside the relevant standards, or if applicants are unsure, they should contact ComReg for clarification. ComReg will endeavour to assess new systems to determine their applicability to the Irish market as they emerge. ComReg is currently assessing some of the technologies mentioned in this Briefing Note and is continuing to follow developments in the relative European and international standards bodies.

[101] As described in Wireless Link technology Briefing Note.

A2.2 Licence Exempt Framework

In Ireland the use of certain radio systems is permitted on a licence exempt basis under the Wireless Telegraphy Act, 1926 (Section 3) (Exemption of Short Range Devices) Order, 2002[102]. Details of the relative frequency bands and required operational characteristics are listed in the 'Permitted Short Range Devices in Ireland' document on the ComReg website - http://www.comreg.ie/_fileupload/publications/odtr0271.pdf .

A2.3 Test Licenses

A test licence framework exists for new radio equipment, new radio spectrum applications and/or new radio services. An application form and guidance notes are available on the ComReg website - http://www.comreg.ie/_fileupload/publications/ComReg9915R.pdf

A2.4 Point to Point Links Licensing

The Application procedure for point to point radio links above 1 GHz is described in the "Guidelines for Applicants for Point to Point Radio Links in Frequency Bands above 1 GHz" document - (http://www.comreg.ie/_fileupload/publications/ComReg9814R3.pdf). In accordance with the guidelines, applications for Point to Point Links above 1 GHz should be made to the Commission using the application form – (http://www.comreg.ie/_fileupload/publications/ComReg9815R3.pdf)

A2.5 Fixed Wireless Access Licensing

Information on Fixed Wireless Access Licensing in the various bands can be found on the ComReg website in the following documents:

Registration of 5.8GHz Wireless Access Base Stations	http://www.comreg.ie/_fileupload/publications/ComReg0342.pdf
Guidelines to Applicants for Local Area Fixed Wireless Access (FWA) Licences	http://www.comreg.ie/_fileupload/publications/ComReg0334.pdf
Guidelines to Applicants for Fixed Wireless Access Local Area - 3.5GHZ Licences	http://www.comreg.ie/_fileupload/publications/ComReg0397.pdf
Convergence of Mobile and Fixed Technologies Extending Broadband Access within Licensed GSM Radio Spectrum – Responses to Consultation Document 03/63	http://www.comreg.ie/_fileupload/publications/ComReg03104.pdf

[102] SI Number 405 of 2002. Note that other systems, such as certain satellite terminals, are also permitted for licence exempt use under separate legislation.

10 Annex 3 – Glossary

ATM	Asynchronous Transfer Mode
BRAN	Broadband Radio Access Networks
CD	Compact Disc
CEPT	European Conference of Postal and Telecommunications Administrations
CERN	European Centre for Nuclear Research
DNS	Domain Name Service
DSL	Digital Subscriber Line
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FSO	Free Space Optics
HEAnet	Higher Education Authority network
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv6	Internet Protocol version 6
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
IT	Information Technology
ITU	International Telecommunication Union
LAN	Local Area Network
LHC	Large Hadron Collider
MAN	Metropolitan Area Network
MANET	Mobile Ad-hoc Networks
MBWA	Mobile Broadband Wireless Access
MMIC	Monolithic Microwave Integrated Circuits
MOTERAN	Mobile Telecommunications Radio Relay Network
P2P	Peer to peer
PAN	Personal Area Network
PC	Personal Computer
QDMA	Quadrature Division Multiple Access
RF	Radio frequency
RIAA	Recording Industry Association of America
RPR	Resilient Packet Ring
SAN	Storage Area Network
SIG	Special Interests Group
SME	Small to Medium sized Entity
SRD	Short Range Devices
T-Ray	Terra hertz electromagnetic radiation
UMW	Upper Millimetre Wave
UWB	Ultra Wide Band
Wi-Fi	Wireless Fidelity (WLAN)
WLAN	Wireless Local Area Network
XML	eXtensible Mark-up Language