Open Spectrum UK Response to Ofcom's "Spectrum Framework Review" Consultation

15th February 2005

Contents

Open Spectrum UK

The following response to Ofcom's Spectrum Framework Review is submitted by Open Spectrum UK.

Open Spectrum UK is an ad hoc coalition of non-profit organisations engaged in community wireless networking and the promotion of license-free access to the public airwaves. The availability of spectrum for license-exempt use has enabled us to develop cost-effective, user-owned networks to provide Internet access and localised information services for the benefit of many thousands of UK residents. Reflecting on the topics raised in the document presenting Ofcom's "Spectrum Framework Review," we found agreement with each other on numerous issues and therefore decided to submit a collective response – "we" being:

Access to Broadband Campaign (ABC)
ABC exists to promote universal access and affordability of broadband in the UK. Recipient of the 2003 CNET Networks Award for Outstanding Contribution to UK Technology, with specific reference to the promotion of license-exempt wireless as a first mile broadband solution in remote and rural areas[1]
http://www.abcampaign.org.uk

Alston Cybermoor
A community wireless network in rural Cumbria, Alston Cybermoor is an exemplar of the Broadband Britain funded pilot projects using license-exempt 802.11 wireless broadband technology to promote regional economic development. Alston Cybermoor was formed in 2002 and is constituted as an Industrial and Provident Society. Widespread community support has led to over 30 % take up of the broadband service, and innovative local services have been developed including an online channel for community produced digital content.
http://www.cybermoor.org

Arwain.net
A community wireless network based in Cardiff, Arwain was formed in the summer of 2001 and officially launched in October 2002 by Andrew Davies, AM, Economic Development Minister and e-Minister for the Welsh Assembly Government [2]. Arwain is constituted as a non-profit company, and is engaged in a number of social regeneration projects in south Wales.
http://www.arwain.net

[1] Matt Loney, Broadband access dominates UK tech awards, 9 Oct 2003:
http://news.zdnet.co.uk/communications/broadband/0,39020342,39117019,00.htm

[2] Rob Andrews, Wireless web boost for Wales, 8 Oct 2002:
http://news.bbc.co.uk/1/hi/wales/2311193.stm

Boundless

Boundless is a broadband co-operative established during 2004 in the London Borough of Lewisham which presents a self-provisioned wireless mesh network, a high speed network optimisation of broadband resources across the residential, small business, educational, cultural and digital media communities. It draws on the Consume.net[3] proposition and a wealth of local experience.
http://boundless.coop

Community Broadband Network (CBN)
Founded in 2003 with funding from DTI, DEFRA, Countryside Agency, Co-operative Action and Cisco, the Community Broadband Network seeks to provide a support network for community broadband projects across the UK. Constituted as a co-operative for the benefit of local broadband projects, CBN provides expert advice and supports the development of joint services. A recent survey by CBN identified local broadband initiatives in over 550 towns and villages in the UK, the vast majority using license-exempt spectrum to deliver their services.
http://www.broadband-uk.coop

Foundation for Information Policy Research
The Foundation for Information Policy Research is an independent body that studies the interaction between information technology and society. Its goal is to identify technical developments with significant social impact, commission and undertake research into public policy alternatives, and promote public understanding and dialogue between technologists and policy-makers in the UK and Europe.
http://www.fipr.org

[3] Consume.net http://cosnsume.net

GreenNet
GreenNet Ltd is a UK-based Internet Service provider that has been supporting community networking for peace, the environment, gender equality and social justice, through the use of Information Communication Technologies (ICTs), for the last 18 years. It is wholly owned by its parent charity, The GreenNet Educational Trust (registered charity no.1037080).
http://www.gn.apc.org

Informal
Informal is a UK registered non-profit organisation formed in 2001, which provides a framework for collaborative research focussed upon social development and technology. Recent engagements have included community wireless networking and wireless freenetworks in both the developed and the developing world. Informal has recently published a survey of license-exempt wireless network usage in London.[4]
http://informal.org.uk

Open Spectrum International
Open Spectrum International is a global policy advocacy project based in Prague, Czech Republic. Launched last summer by the Czech civic association "Mista v Srdce," its goal is to increase license-exempt access to the radio spectrum.
http://www.open-spectrum-international.org

Wireless London
Wireless London is a non-profit umbrella group that promotes the growth of London's vibrant and pioneering Free Networks. Working with architects, city planners, artists, technologists and the creative industries, Wireless London makes the case for Free Networks as a future urban infrastructure for London - a civic technology that privileges community learning, investment and interest. Wireless London is a strategic project funded by the Arts Council of England.
http://wirelesslondon.info

[4] See Julian Priest, "The State of Wireless London" (2004): http://informal.org.uk/people/julian/publications/the_state_of_wireless_london/.

Introductory Remarks

Open Spectrum UK appreciates the opportunity to contribute to this important and fundamental reconsideration of national spectrum policy in the UK.

Whilst we generally support Ofcom's efforts to introduce greater flexibility and efficiency into spectrum utilisation, our "Response to Consultation Questions" below focuses on specific aspects for which we have criticisms or supplementary information.

Yet we need to preface our Response with some broader observations appropriate to the magnitude of the changes proposed by Ofcom with regard to radio regulation. A "statutory obligation" is noted on page 24 of the consultation document:

> "Where the use of any particular equipment for wireless telegraphy is not likely to involve undue (harmful) interference, Ofcom must exempt the use of that equipment from the requirement to hold a wireless telegraphy license."

Though this is rarely stated explicitly, that obligation - imposed by the European Union's framework for electronic communications - is rooted in the European Declaration of Human Rights (EDHR). Article 10 of the EDHR asserts that everyone has the right "to receive and impart information and ideas without interference by public authority." Licensing is an "interference by public authority" and as such it is permitted by the EDHR only for "broadcasting, television or cinema enterprises" or when "prescribed by law and…necessary in a democratic society…[for] public safety, for the prevention of disorder," etc. When licensing cannot be justified by any of these exceptions, it must be considered a violation of human rights.

After a century of development, we finally see license-free radio technologies with enough built-in intelligence to produce self-organisation and resilience to interference rather than chaos and disorder - under controlled conditions, perhaps, but already on a scale that is economically, socially and politically significant. This is an epochal shift whose importance is not reflected in the amount of spectrum proposed by Ofcom for future license-exempt use.

The justifications given in the current consultation for utilising market forces refer to maximising economic benefits and spectrum efficiency. However, one must not forget that the regulation of radio was instituted internationally not to control interference but to reign in the business practices of the Marconi Wireless Telegraph Company. No radio firm today has the patent position or monopoly ambitions of a Marconi. But that era should remind us that naked economic forces are not always benign. Unless sharing is explicitly mandated, the essence of radio licensing is the creation of localised, frequency-based monopolies. Only time will show if competition law can reign in the forces unleashed by "liberalised" licensing.

Response to Consultation Questions

Question 1

Are there any other major medium- to long-term spectrum management issues that this review should be considering? Are there any other significant technological or market developments that this review should be aware of when developing its thinking?

Software-Defined Radio (SDR) and Cognitive Radio (CR) are major medium- to long-term spectrum management issues which this review should consider in more depth.[5] SDR is mentioned only briefly on pages 19 and 39 of the consultation document, where it is dismissed as a synonym for CR. However, SDR and CR are more clearly distinguished in the consultation paper's **Glossary**:

> *"**Software defined radio**. A radio whose characteristics are set by software, not hardware, which as a result can change itself considerably to adapt to situations*." (page 79)
>
> *"**Cognitive radio** - A radio which can sense when a piece of spectrum is not being used, adapt itself to fit the spectrum, transmit briefly and then move onto the next free piece of spectrum."* (page 78)

Software gives SDR some functionalities that electronic circuitry and hardware switches were expected to provide in earlier radio designs, along with new functionalities and gains in flexibility. SDR's signal processing, for example, can be altered quickly and conveniently by changing a few symbolic parameters rather than by replacing electrical components. One can drastically alter the signal output even while the radio is operating - not just "to adapt to situations" as the **Glossary** says, but to test new settings or cause intentional interference. SDR references the device's inner workings, while CR describes interactions with the environment. Reprogrammability need not be linked to protocols for automatic or "smart" adaptation to nearby signals, as with CR.[6]

A driving factor in the development of SDR is that information processing costs seem always to decrease, so that at some point, it is likely to be cheaper to implement certain radio functions in software rather than in hardware. Kevin Kahn, director of Intel's Communications Technology Lab, told a European Commission workshop on "Research & Technology Development and Spectrum Policy" last November that it might take 20 years for all radio functions to be cheaper to implement in software, but some functions are cheaper already, implying that we will probably see a gradual shift to SDR over several decades.[7] Other experts note that SDR will probably have a earlier and wider impact on receiver design than on transmitters. Indeed,

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[5] Cognitive Radio is the focus of our answer to Question 17.

[6] We prefer the definition proposed by the European Commission's TCAM workgroup on SDR: *"a radio where essential parameters - normally subject to regulation - like frequency range, modulation type, maximum output power, etc., can be altered by changing software."* Note that the term Reconfigurable Radio is also beginning to be used in some contexts, instead of SDR. The TCAM workgroup is briefly described below.

[7] "Notes from the European Commission's Workshop on 'Research & Technology Development and Spectrum Policy' (23 November 24)" by Robert Horvitz - http://www.open-spectrum-international.org/ec-workshop.html.

programmable VHF-UHF scanning receivers have been in production for more than 20 years already.

A concern often expressed in connection to SDR is that it could undermine equipment "type acceptance" as a spectrum management tool. Devices whose capabilities are "hardwired" can be expected to behave in the field much as they behaved in the testing laboratory or when their R&TTE conformance was certified by the manufacturer. However, to the extent that they can be easily reconfigured after purchase, SDRs offer no such assurance. This is particularly true when open standards define their hardware/software interface.

Type acceptance has helped limit harmful interference in the license exempt bands. Indeed, we regard type acceptance as a viable alternative to licensing, in many cases, and crucial for expanding the spectrum available for license-exempt use. Weakening the safeguards provided by type acceptance could increase the risk of the spectrum for license exempt devices becoming too noisy and unpredictable for practical communication. The same risk exists for licensed bands, of course, but the occupants of license-exempt bands have no right to call on public authorities for relief in specific cases of harmful interference.

Europe is already phasing out the testing and authorisation of radio equipment by regulators, and relying increasingly on manufacturers' "declarations of conformance" to the Radio and Telecommunications Terminal Equipment (R&TTE) Directive, 1999/5/EC.[8] But self-certification by manufacturers is meaningless when their equipment can be significantly reconfigured after purchase. Realising this, the European Commission's Telecommunication Conformity Assessment and Market Surveillance Committee (TCAM) formed a workgroup in December 2001 to explore the challenges posed by SDR to the R&TTE Directive. The workgroup held a public consultation from 30 June to 30 September 2003[9] but so far as we know, the results have not yet been published.[10]

However, it is wrong to treat SDR simply as a threat. Michael Powell, departing chairman of the US Federal Communications Commission, said that "the potential of this technology is immense - it cannot be overstated."[11] SDRs can go a long way toward solving interoperability problems and facilitating the redeployment of equipment, as is essential if Ofcom's vision of more flexible spectrum use is to be realised.[12] SDR could significantly reduce the cost of retasking equipment when it is transferred from one license holder using type "X" modulation in channel "Y," to another license holder who needs it to use type "Z" modulation in channel "W."

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[8] See http://europa.eu.int/comm/enterprise/rtte/dir99-5.htm

[9] See http://europa.eu.int/comm/enterprise/rtte/questionn/index.htm

[10] See "Regulation of SDR in Europe" by Paul Bender, presented at the "Regulatory Round Table on Software Defined Radio" (London, 15 September 2003) - http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/converge-new-emerging/sdr/9-bender.pdf

[11] Quoted by Mike Chartier in "US SDR Regulation," presented at the "Regulatory Round Table on Software Defined Radio" (London, 15 September 2003) - http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/converge-new-emerging/sdr/7-chartier.pdf

[12] See "Dynamic Spectrum Allocation (DSA) and Reconfigurability" by David Grandblaise, Didier Bourse, Klaus Moessner and Paul Leaves, paper presented at the "SDR Forum" (San Diego, California, 13-15 November 2002) - http://www.comnets.rwth-aachen.de/~o_drive/publications/DSA_and_Reconfigurability.pdf

Similarly, the upgradability inherent in SDR means longer equipment replacement cycles - potentially reducing the total cost of ownership.

Finally, there are realistic hopes that SDR developers will find protocols and etiquettes supporting increased resistance to interference through improved coding of RF signals and enabling more efficient use of the radio spectrum. Some of the breakthrough products now fuelling the market for mesh networks were initially developed through experimental modification of the software drivers for Wi-Fi equipment - and British innovators from the license-exempt community have made important contributions in this field, which is now generally recognised as one of the most exciting trends in wireless communication. We share Ofcom's desire to encourage innovation, and SDR is an area of active research and development showing much promise. The regulatory goal obviously should be to reduce the risk of harmful interference without foreclosing the potential benefits of improved technology. The extreme flexibility of SDR creates a high-risk/high-reward situation so that care must be taken to get the regulatory framework right.

To that end, we encourage Ofcom to organise its own public consultation about SDR in the near future.[13] It is our impression that regulators around the world have not yet reached a consensus on how to deal with SDR, even though they recognise it as a technological evolution that is promising, problematic and probably inevitable. Ofcom should not try to cut the Gordian knot simply by excluding SDRs from license exempt bands. If SDRs are excluded, and there is a gradual shift from hardware to software in the design of radio equipment - as predicted by Intel and others - then the range of equipment allowed to operate in license-exempt bands will gradually tend toward zero.

Question 2

Do you believe it is useful to publish a compendium of issues? How frequently should it be published? What information should be included?

On page 6 of the consultation document Ofcom say, "We will achieve [our Spectrum Vision] by: Providing spectrum for license-exempt use as needed…"

The phrase "as needed" implies that Ofcom will periodically assess whether the spectrum allocated to license exempt activities and services is in fact sufficient to satisfy the public's needs.

We urge Ofcom to adopt in the near future a formal procedure for these periodic assessments. The procedure might include technical studies designed to measure occupancy of the spectrum available for license-exempt use in certain populated areas at 2 year intervals; low-flying aerial surveys; public consultations on the need to change current band allocations or power limits for license-exempt devices; annual market survey reports on UK sales of short-range devices of various types; a quarterly count of complaints symptomatic of bandwidth congestion; etc.

The pace and timing of some elements of the needs assessment might be linked to production of the "compendium of issues" proposed on page 16 of the consultation document. But even if no linkage is made, we think the compendium would help

[13] No such activity is listed in OFCOM's *Annual Plan 2005/06*. The United States, Germany and Japan have already held national consultations on SDR.

educate the public about issues being considered by Ofcom and increase the transparency of regulatory activities. Familiarising the public with issues which may be the subjects of later consultations is also likely to increase the quantity and usefulness of the responses received during the consultations.

Question 7

Do you agree with Ofcom's approach to providing spectrum for license-exempt use?

We will first summarise some salient points of Ofcom's approach and then comment on them:

A) Ofcom has a statutory obligation noted on page 24 of the consultation document:

> *"Where the use of any particular equipment for wireless telegraphy is not likely to involve undue (harmful) interference, Ofcom must exempt the use of that equipment from the requirement to hold a wireless telegraphy license."*

B) According to the "Telegraphy (Exemption) Regulations 2002...there is not actually any license-exempt spectrum. Instead there is spectrum that Ofcom has chosen to set aside solely for license-exempt devices using a particular technology or range of technologies." (Page 24)

C) "Ofcom's light-touch philosophy biases it towards deregulating access to spectrum where possible and appropriate." (Page 23) *Therefore, Ofcom will provide "spectrum for license-exempt use as needed, but our current estimates are that little additional spectrum will be needed in the foreseeable future, growing to 7 per cent of the total spectrum..."* (Page 6)

D) "Our calculations show that if there were 800MHz of spectrum available for license-exempt use then every person could have 100Mbits/s short range services – more than enough to allow simultaneous high definition TV, browsing and on-line gaming. With around 600MHz of spectrum already available for license-exempt use, of which over 400MHz has only very recently been made available, a small additional expansion is all that is needed to create significant benefits, although we have not identified specific frequencies yet. Expanding beyond this would result in unused spectrum. This is an area we need to keep under careful review as applications and demand grows." (Pages 3-4)

E) "As a maximum, then, an additional 250MHz or so of spectrum might be needed for license-exempt use. Given the technologies will generally work better with contiguous spectrum, this might best be allocated close to the existing 5GHz band, although no specific frequencies have been identified at this point." (Page 26)

F) "In rural areas where less demand is predicted, we believe that we can allow an increased range for license-exempt use to reflect the lower probability of interference. We would welcome views on this... We will consult on the most appropriate mechanisms to define areas where higher powers are permitted... Ofcom is concluding its examination of the possibility of allowing higher power in the 2.4 GHz license exempt band and will be publishing its conclusions in due course..." (Pages 46-47)

G) "The next stage is to... compare the economic benefits of license exempt usage with the benefits of licensed usage. As mentioned above, this is a difficult comparison as it requires forward-looking assessments of the best use of the spectrum. However... it seems unlikely that immediately providing additional spectrum will be economically sensible. Therefore, instead, Ofcom proposes to monitor the usage of the 5GHz band in order to predict when demand in the band might exceed capacity." (Page 26)

(H) License-exempt devices must not use "cognitive access" to spectrum not provided for license exempt use (summarising pages 39-41), but "spectrum should be made available for license-exempt use where there is a low probability of congestion..." (Page 46)

Our comments: Ofcom's "light-touch philosophy" is a most welcome development which we hope will endure and spread throughout Europe and into other regions. We enthusiastically support the quest for alternatives to the traditional "command and control" approach to spectrum management, as well as Ofcom's pledge to "make every effort to encourage the emergence of new technologies as long as they help achieve the objective of optimal spectrum usage." (Page 5)

In our view, license-exempt devices are major contributors to "optimal spectrum usage" through their intensive reuse and sharing of frequencies; robust link performance in the presence of noise and interference; and provision of an ever-expanding variety of services not available from radio license holders. The availability of spectrum for license-exempt devices has proved a stimulant to creativity and experimentation among inventors and entrepreneurs. "Next to slow developments being made in the licensed bands, formidable progress is made in the unlicensed band(s)," note the authors of *Rethinking the European ICT Agenda*.[14] Whether one interprets "optimal" in terms of benefit to the most people, or maximizing economic gains from inputs, or value in comparison to other potential uses of the same frequencies, license-exempt devices are the spectrum success story of the decade.

We understand the distinction made between spectrum which is license-exempt and spectrum available for use by particular devices which are license exempt. Three important implications seem to flow from that distinction. First, exclusive allocation is not necessary for license-exempt devices. Regulations can be crafted to permit license-exempt devices to operate in bands whose primary (and even secondary) users are licensed. However sceptical Ofcom may be about license-exempt "cognitive access," there is little doubt that band-sharing between licensed and license-exempt users will increase, if only because of Ultra-WideBand.

Second, equipment type acceptance is the key that unlocks access to bandwidth for license-exempt devices. So long as Ofcom does not try to define "a particular technology or range of technologies" too restrictively - forbidding harmless variations, novel applications and improvements - we see type acceptance as a safeguard against the selfish behaviours which can cause a "tragedy of the commons." Over the course of the next 5-10 years, type acceptance will enable license-exempt devices to play a

[14] *Rethinking the European ICT Agenda: Ten ICT-Breakthroughs for Reaching Lisbon Goals*, PricewaterhouseCoopers, published by the Dutch Ministry of Economic Affairs, Directorate-General Telecommunications and Post, August 2004, page 56.

leading role in the development of "responsive environments" for a society which is "always connected."

A third point following logically from the assertion that "there is not actually any license-exempt spectrum" is that users of license-exempt devices should not have to pay anything for spectrum. This is the policy of most advanced countries now. Japan's Ministry of Internal Affairs and Communications, for example, recently decided to waive the Spectrum User fee for "radio stations not requiring licenses, which do not occupy specific frequency bandwidths."[15] However, license holders in the UK may someday argue that it is unfair for them to pay so much for resources that the users of license-exempt devices get for free. We would argue that the rights and benefits arising from licensed and license-exempt frequency use are hardly comparable. What the license holder pays for is 1) the right to protection from interference; 2) the right to resell and rent rights conveyed by the license; 3) the market value of geographically exclusive frequency use; 4) opportunities for speculative gain in reselling the license; and 5) in the original purchase, compensation to Ofcom for services rendered. Collecting a spectrum use fee from the manufacturers of license-exempt devices is also unfair since they are not the actual users of the spectrum. Ofcom is choosing to maintain portions of the radio spectrum as license-exempt commons presumably because it expects this will produce more desirable social outcomes than applying property-orientated rules to all non-government and non-scientific bands. Charging individual commons-user fees reduces that differentiation.

In point C) above, the most important element is Ofcom's flexibility about the quantity of spectrum to be made available for license-exempt use, and the statement of intent to provide more when needed. We applaud that position, although it is undermined by the use of the words "maximum" and "ceiling" to describe the preliminary estimate of needed bandwidth.[16]

Note that our ability to exploit the radio spectrum is gradually expanding "up-band." Affordable equipment capable of generating and detecting RF energies above 30 GHz is a recent development, and in this frequency range, where the available bandwidth is many times greater than all the spectrum used in the first 50 years of radio development, propagation is severely limited by environmental absorption. As the FCC Spectrum Policy Task Force's Unlicensed Devices and Experimental Licenses Working Group note in their *Final Report*,

> "While it is difficult to say what regulatory approach should be used for millimetre wave spectrum [above 30 GHz], the physics of this band are so different than lower bands as to bring into question most of the fundamental precepts of radio regulation. This results both from the high propagation losses due to gas absorption of radio signals and the ease of building antennas with very narrow beams. While licensing is the general presumption at lower frequencies, the physics of these frequencies appear to justify a *de novo* approach to considering regulatory schemes on a case-by-case basis. It may well be reasonable to question whether unlicensed use should be a

[15] "Final Report of the 'Study Group on Policies for Effective Radio Spectrum Use' Compiled," *MIC Communications News*, 2 November 2004 - http://www.soumu.go.jp/joho_tsusin/eng/Releases/NewsLetter/Vol15/Vol15_15/index.html#2

[16] "By understanding the reuse factors needed in urban environments, a ceiling on the amount of spectrum needed for licence-exempt use can be reached. Ofcom's initial view is that around 800MHz of spectrum might be sufficient..." (Page 26). "Maximum" is used on the same page and quoted above at point E).

> major type of use in these higher bands, rather than one restricted to a small set of bands..."[17]

Since there are still large blocks of unassigned frequencies in the higher bands, putting a "ceiling" on the bandwidth available for license-exempt technologies of 800MHz or 6.9 percent of the total allocated would seem to foreclose the possibility of license-exempt activity in the higher bands, even though it would be eminently practical there. Instead, we encourage Ofcom to seriously consider the option of not having licensing as the default policy for bands above 30GHz.

However, we agree with Ofcom's quest for a contiguous and exclusive allocation for license-exempt devices around 5GHz. We also encourage the designation of different bands for use by different types of license-exempt devices - perhaps through type acceptance - while recognising the possibility of special compatibilities among dissimilar technologies and allowing for innovations which stretch the purpose of a specific band. It is a quirk of history that Wi-Fi became popular in a band originally created for aluminium forges, kidney dialysis machines and microwave ovens, and it is still not easy for WLANs to co-exist with such strong RF noise sources. RFID tags and movement-detectors have a small non-exclusive allocation around 13MHz, and automotive radars are getting a wide (non-exclusive) band around 76GHz. Such segregation of short-range devices by band can increase the intensity of spectrum utilisation, improve performance and reduce equipment costs.

Concerning point H), the consultation document contains conflicting criteria for making additional spectrum available for license-exempt uses. This should be clarified. One stated criterion is that spectrum will be made available when there is both a need and an economic advantage. Another is that "spectrum should be made available for license-exempt use where there is a low probability of congestion." The latter was stated in a specific context (wireless broadband access), so perhaps it was not intended as a general policy. Nevertheless, we recommend it as a general policy, complementary to the use of congestion as a trigger for considering increases in dedicated spectrum.

Ofcom may be aware that the InfoComm Development Authority of Singapore recently raised the power output levels permitted for WLANs in the 2.4 and 5.8GHz bands, despite the fact that the population density of Singapore is nearly 50% greater than London's. That density, plus the fact that Singapore has one of the most highly developed ICT infrastructures in Asia, suggest that the density of WLAN access nodes in the 2.4GHz band is higher in Singapore than in London. Yet for license-exempt 2.4GHz systems, the output permitted has increased from 100 to 200mW; in the 5.8GHz band, "the power limit has been raised from 100mW to one watt (W), license-exempt, and 4W for licensed use..." IDA's objective is to expand wireless Internet connectivity while reducing the number of access points needed by a network to serve an area and thus reduce equipment costs.[18] Ofcom should take Singapore's decision as encouragement to consider similar power increases for the UK as a whole, and not just in rural areas.

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[17] *Final Report of the Unlicensed Devices and Experimental Licenses Working Group*, Spectrum Policy Task Force, US Federal Communications Commission, November 2002, page 11.

[18] "IDA Makes Wireless Networks Cheaper" by Amit Roy Choudhury, *Business Times,* 21 Jan 2005 - http://it.asia1.com.sg/newsdaily/news002_20050121.html.

As for basing the expansion of spectrum available for license-exempt activities on Ofcom's monitoring of congestion in the 5GHz band, the largest expansions of frequency demand in the license-exempt domain during the next 3-5 years are likely to come from the proliferation of RFID tags and Ultra-WideBand technologies - neither of which impact the 5GHz band. Nor will monitoring 5GHz detect congestion in other parts of the spectrum (2.4GHz for example), and not all services suffering congestion in other bands can move to 5GHz. The migration of many WLANs from 2.4 to 5GHz is practical, but Ofcom should also monitor other bands (including those allocated to terrestrial analogue broadcasting) and treat the persistent under use of bands by license holders as an opportunity to expand license-exempt activity.

Accelerating technological change, increasing competition for spectrum, and more heterogeneous band use will soon make radio regulation more complex - even if the regulator is no longer responsible for all details. When decisions which were the responsibility of a central authority are delegated to the marketplace, there will be a need for a more collaborative process of spectrum management. Thus, Ofcom may find it useful to establish a Wireless Regulation Forum to act as a channel of communication with all stakeholders.

Question 8

Is Ofcom's proposed methodology to estimate the amount of spectrum provided for license-exempt use likely to deliver the right results?

Ofcom has not provided sufficient information about its proposed methodology for us to evaluate whether it delivers the "right" amount of spectrum for license-exempt use.

The methodology used thus far to estimate the total bandwidth needed – "ITU-R M.1651" - was developed to estimate the spectrum needs of "nomadic wireless access systems" operating near 5 GHz. Such models require data or assumptions about the future market for wireless services and equipment. These are presently quite uncertain, if one wants to project 5 years into the future, and Ofcom has not revealed its assumptions. So we are even less sure than Ofcom that their estimate is realistic for networks with topologies and use scenarios very different from HIPERLAN's. But mathematical modelling is just a start. Ofcom state repeatedly that it intends to monitor occupancy in the license-exempt bands - particularly at 5GHz - and make more spectrum available "as needed." However, no methodology for measuring band utilisation is given. Indeed, footnote 18 of the consultation document laments the difficulty and imprecision of the process, concluding: "Ofcom would welcome suggestions on approaches to measuring occupancy." An additional layer of unknowns is then introduced: "The next stage is to... compare the economic benefits of license exempt usage with the benefits of licensed usage. As mentioned above, this is a difficult comparison..." (Page 26) From these remarks we conclude that Ofcom have not fully formulated their methodology, but it will combine mathematical modelling, monitoring, economic analysis and suggestions from others which have not yet been evaluated.

Ofcom assert that 800MHz of bandwidth "would allow all users in an office or home environment to have access to 100Mbits/s transmissions under most normal situations." (Page 26) Although it unclear if this estimate refers to peak or average bandwidth, we urge that the terms "ceiling" and "maximum" not be used to characterise it, especially while the qualifying phrase "under most normal situations"

is appended. There is substantial diversity in living and working situations which is difficult to capture in mathematical models. On the other hand, a market forecast published last year by Jupiter Research predicts that

> "Bandwidth requirements for the typical broadband home with a wireless network will grow from less than 3 Mbps in 2004 to a likely 57 Mbps in 2009, with tech-savvy households of three individuals requiring up to 84 Mbps, driven primarily by changes in home use of consumer electronics and changing consumption patterns for digital media at home..."[19]

While it is reassuring that Jupiter Research's estimate of the bandwidth needed by "tech-savvy households" is less than Ofcom allows for "each person," it may be more significant that the bandwidth needed for in-home use in only 5 years is forecast to be 19-28 times last year's figure, and there is no reason to assume that growth will abruptly halt in 2009. Another point is that the bandwidth demand in "tech-savvy households" is expected to be nearly 50% greater than average households. Does Ofcom equate "average households" with "under most normal situations"? If so, then what about the "tech-savvy," who might need 50% more bandwidth? These considerations underscore the need for flexibility in estimating future license-exempt bandwidth requirements.

In fact, as Ofcom well know, it is very difficult to determine the capacity of a band occupied by a mix of different systems types, all of which must accept interference. One must make assumptions about their proximity and duty cycle, how much degradation of service quality users can tolerate, and what relative proportions in the mix reflect user preferences and social policy goals.

This is demonstrated by *Evaluating Spectrum Percentage Occupancy in License-exempt Allocations*, an analysis commissioned by Ofcom and delivered last July.[20] The authors of this study try to estimate the capacity of the 2.4GHz band when populated by WLANs, Bluetooth devices, microwave ovens and electronic newsgathering kits. Several mathematical models are considered - not including ITU-R M.1651, we note - and reasonable assumptions are made about deployment geometry, quality of service, the effects of walls, etc. Maximum densities are calculated for each type of device as well as the interaction of certain device pairings. The authors conclude that "full occupancy" of the 2.4GHz band by WLANs is reached with 24.79 access-points in 1 square kilometre.[21] However, the authors also note that the "number of devices that can be placed successfully in an area does not scale linearly with area (i.e. constant density) because there are more interfering sources aggregating in effect at each victim receiver."[22] Extrapolating the curve in the chart on page 56 of the report (reproduced below), it appears that full occupancy of the 2.4GHz band occurs with about 13 WLAN access points per square kilometre in an area the size of London - if no other device types are active.

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[19] JupiterResearch press release announcing *A Portrait of the Wireless Digital Home in 2009* - http://www.jupitermedia.com/corporate/releases/04.11.04-newjupresearch.html.

[20] *Evaluating Spectrum Percentage Occupancy in Licence-Exempt Allocations - Final Report* by Paul Hansell, Selçuk Kirtay, Iain Inglis, John Pahl and Steve Munday, Aegis Spectrum Engineering and Transfinite Systems Ltd., 7 July 2004 - http://www.ofcom.org.uk/research/industry_market_research/technology_research/ses/ses2003-04/ay4529/perc_ocp_lisc.pdf.

[21] "Full occupancy" means that no additional systems can be deployed without reducing the quality of service below a certain threshold for a certain number of systems.

[22] *Op.cit*., page 56.

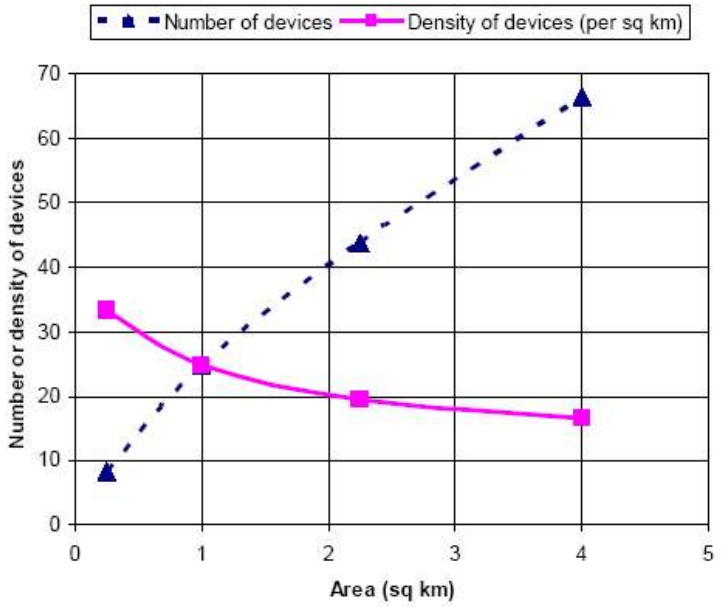

Figure 25: Number or density of WLANs with area

If one includes the effects of 100 home microwave ovens per square kilometre, the number of WLANs constituting full occupancy is reduced to about 5.5 access-points per square kilometre.[23] Add in 1000 Bluetooth devices per square kilometre, and the density of WLANs providing the minimum quality of service is reduced to about 4 per sq/km. (The authors did not attempt to calculate full occupancy by WLANs in the presence of more than one other device type, so we have had to make our own assumptions to include both Bluetooth and microwave ovens.) Include electronic news gathering kits and other ISM devices, and the WLAN capacity is reduced even further. But let us put those in our margin of error and compare the estimated capacity of the 2.4GHz band to the number of "hotspots" known to be operating in London. Such a survey is provided in "The State of Wireless London" by Julian Priest[24]:

> "In order to get a current snapshot of the whole of London we contacted Capital Radio, who offered the use of their traffic spotter plane 'The Flying Eye' as a platform from which to get an aerial overview... [On] 22nd Feb 2003 James Stevens hitched a ride in the 4 seater plane. Using a directional antenna, a GPS and a laptop running network discovery program Netstumbler, he found 1525 nodes along the flight path...

Total Distance flown	348.4 km
Radius of view	~0.5 km
Flight height	~0.4 km
Ground area covered	~0.3 km^{-2}
Total area covered	~98 km^{-2}
Node density	~15.5 nkm^{-2}
Estimate of nodes within the M25	~19451

> "This is a very rough order of magnitude calculation and only takes into account those nodes visible to the air and with a sufficient signal strength to reach the plane

[23] This is our extrapolation for an area the size of London. The authors only calculate occupancy for 1 square kilometre.

[24] http://informal.org.uk/people/julian/publications/the_state_of_wireless_london/.

> at its cruising altitude. Normal access points with standard antennas are unlikely to show up on this survey as the flight altitude was at the limit of their range, normally taken to be 250m. However the main point of the study was to show that there is a large installed base of nodes that cover London with a fairly complete wireless cloud, far in excess of the publicly displayed node maps of either the commercial operators or freenetworkers..."

It is safe to assume that a measured node density of 15.5 per square kilometre understates the real density, not only because the survey antenna was at the limit of the desired signals' propagation range, but because the survey was conducted 2 years ago. The growth in 2.4GHz WLANs has accelerated since then.[25]

In other words, our extrapolations from the Aegis/Transfinite results suggest there already could be at least 4 times as many wireless access points in London as constitute "full occupancy" of the band. That implies either the current allocation of bandwidth at 2.4GHz is seriously inadequate for WLANs, or the Aegis/Transfinite determination of "full occupancy" is flawed - or both. (Since Netstumbler identifies access points by their unique MAC address, there is no chance of over counting in the aerial survey.) Therefore we suggest there is immediate need for congestion relief in the 2.4GHz band in London, and at the same time we caution against relying too much on mathematical models.

Approaching the problem of estimating the bandwidth needed for license-exempt devices from another angle, we note that Japan's strategic plan for radio frequency management - its "Radio Policy Vision" - calls for expansion of the license exempt spectrum just for WLANs to 740MHz over the next 10 years (mostly in the region around 5GHz), and in addition, it proposes that Japan should become a "ubiquitous network society" with embedded RFID tags and wireless sensing/monitoring systems permeating all populated areas. Additional spectrum - beyond the amount needed for WLANs - is required for those other services, although the quantity is not yet known. Still more spectrum will be needed for home entertainment, although for that they may rely on Ultra-WideBand which does not require dedicated spectrum.[26]

Elsewhere in our response to this consultation we point out that Ofcom seem to ignore the possibility of the spectrum above 30GHz being primarily license-exempt, since the propagation characteristics of the "millimetre band" make that practical. That step alone would increase the total amount of spectrum available for license-exempt use by about 3 orders of magnitude, although its use would need to be coordinated and these frequencies are not suitable for many applications.

Finally, we note with approval that Ofcom is considering permitting higher power output for license-exempt WLANs in areas where there is little risk of congestion. That might also affect calculations of the total bandwidth needed for license-exempt activities.

Question 10

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[25] Ofcom might also consider aerial surveys as a fast and cost-effective way to sample occupancy in the bands available for licence-exempt use. A comparison of the results of an aerial survey with the results of a longer duration ground-level survey in an area surveyed from the sky would provide a means for determining the degree of undersampling from the air.

[26] See "Outline of Report on 'Radio Policy Vision,'" 30 July 2003, Special Department for Radio Policy, MPHPT - http://www.soumu.go.jp/joho_tsusin/eng/features/radio_policy_vision.pdf.

Do you agree with Ofcom's longer term proposals for spectrum trading?

In **Section 4.4.1** of the consultation document (pages 27-29) Ofcom discuss "Removing the need for a license in constrained bands":

> "It remains illegal in the UK to install or operate radio without a license except where Ofcom makes regulations to exempt the need for specific licences. In line with new European requirements, Ofcom now has a statutory duty to consider exemption if Ofcom is satisfied that no undue interference will result to other Wireless Telegraphy networks and services, or that there is some national interest safeguard or international treaty arrangement...
>
> "In this new framework, Ofcom is re-examining its need for individual licences, and is actively looking at ways where national interest safeguards can still be met through general authorisation arrangements. A number of currently licensed blocks of spectrum are issued to users with an individual license as detailed below. However, we believe that the need for a license is not primarily driven by the prevention of interference between individual users. We are therefore considering the feasibility of removing the requirement for an individual license. In many areas the requirements for use of the bands will be very similar to that which is required under the current licensing regime, but the need for an individual license may be removed. Where it is not possible to remove the need for individual licences, Ofcom is considering making them easily available via its website for local downloading...
>
> "The final outcome of this initiative will depend on what is feasible and practical..."

We commend Ofcom for taking seriously its responsibilities under EU Directives to use general authorisations instead of individual licences whenever this is practical. However, the UK's current national legal framework seems to offer Ofcom but two choices - individual licences and exemption from individual licences. In light of the UK's membership in the EU, it would seem appropriate - even necessary - to amend the law so as to make general authorisations an option recognised as distinct from both open entry and individual licences. It might also be advisable to amend the law to recognise license exempt activities as a normal legal possibility, rather than as exceptional.

At the same time, there may be a need to review the policy of licensing receive-only terminals, such as television sets. This issue is not specific to "constrained bands. The "statutory duty to consider exemption if Ofcom is satisfied that no undue interference will result" would seem to apply to properly functioning receivers which operate in any frequency band.

With regard to the notion of making individual licences for certain bands "easily available via [Ofcom's] website for local downloading" we would like to encourage that option, noting that the United States launched an "online registration" service on 8 February 2005 for coordinating the shared bands in the 70-90 GHz range.[27] "...Before now, applications in these bands could take months to be processed while the potential interference to government systems was assessed. Under the new system, non-federal users and third party database operators can determine whether a proposed high-speed point-to-point link could be operated without causing interference to government operations, and register the link immediately..."

[27] "NTIA and FCC Launch On-line Registration for High-Speed Wireless Links Sharing Spectrum in the 70-80-90 GHz Bands," 8 February 2005 - http://www.ntia.doc.gov/ntiahome/press/2005/708090website_02082005.htm

As for the specific services being considered for a general authorisation regime, the Aeronautical and Maritime license holders can speak for themselves, as can the Amateur Radio Service. But we would note that the World Radio Conference of 2003 modified the International Radio Regulations to include this paragraph:

> **"25.6 2)** Administrations shall verify the operational and technical qualifications of any person wishing to operate an amateur station. Guidance for standards of competence may be found in the most recent version of Recommendation ITU-R M.1544."

ITU-R M.1544 says*, inter alia*, that the Amateur Service is for "duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest..."[28] Our concern is that the non-commercial character of the Amateur Service should be protected, even as Ofcom considers modifying the Service's licensing regime. With market forces being given a greatly enlarged role in determining the use of other bands, there is no need for such forces to infiltrate the Amateur bands as well.

The evolution of the "Citizens Radio Service" in the United States may be instructive in this regard. Created by the FCC in 1948, it was allocated the entire 460-470 MHz band. Unlike all previous two-way radio services it was intended to be open to the general public, without elaborate license requirements, occupational qualifications or tests of knowledge. But within a decade, businesses had become the primary users of CRS. Even though they were authorised to use other bands, it was faster and cheaper to obtain a CRS license and restrictions on who could use the band were weak. Trade and professional associations then petitioned the FCC to make their usurpation of the band official, and in 1957 the FCC reallocated 95 percent of the CRS band for the exclusive use of businesses and police departments.[29]

With regard to Citizens Band Radio, Ofcom "plan to trial the use of the UK bands for a new service, Community Audio Distribution System [CADS]. This is intended to allow religious organisations to transmit their services to the elderly and housebound. The evaluation of the trial will consider the degree to which conventional CB can co-exist alongside this service and after the trial we will review the option of full exemption once again." (Pages 28-29) In general, we oppose channels for interactive communication being re-allocated to broadcasting. A much better solution would be to authorise CADS as a subcarrier service which FM broadcasters could add to their existing signal, outside the range of a standard receiver's passband filter, so that inexpensive demodulating devices extract the audio for the audience that wants it. With 37 per cent of Britons over the age of 55 describing themselves as atheists,[30] we are concerned by the narrow range of content being proposed for CADS.

Question 12

Should Ofcom do more to resolve interference?

We recognise that license-exempt devices are not permitted to cause harmful interference to license holders. But throughout the consultation document there is an

[28] http://life.itu.ch/radioclub/rr/rec-1544.pdf

[29] See "Personal Radio" by Robert Horvitz, *Whole Earth Review*, spring 1986, pages 34-41.

[30] "YouGov/Daily Telegraph Survey Results: Religious Faith," 16-18 December 2004 - http://www.yougov.com/yougov_website/asp_besPollArchives/pdf/STI040101003_2.pdf

implicit assumption that harmful interference is due entirely to the transmitter. This reflects a regulatory policy adopted decades ago to minimise the cost of broadcast receivers, enabling them to be made as cheaply as possible, and at the same time to simplify antenna systems for reception, making them as easy to use as possible. However, the opposite perspective is offered by Robert J. Matheson in "Modern Spectrum Management Alternatives"[31]:

> "A sufficiently good receiver can separate any signals having different electrospace descriptions... Interference is ALWAYS caused by an inadequate receiver and could be fixed by a 'good-enough' receiver (though 'good-enough' for some situations might require adaptive antennas to null out interference, or other complex/expensive tools). Therefore, using better receivers would decrease interference, and/or allow more signals to be transmitted before interference occurred. Therefore, using better receivers would be expected to improve spectrum efficiency."

If Ofcom is serious about improving spectrum efficiency and increasing utilisation, it must look at its rules for radio receiver performance and see what can be done to make them more selective and interference-resistant, without putting unreasonable cost or skill burdens on receiver users.

Question 13

To what extent should Ofcom intervene in promoting innovation?

Since the time of Guiglielmo Marconi, radio amateurs have made significant contributions to the development of wireless technologies. Some of these contributions have grown into major industries - the General Packet Radio Service (GPRS) and low-earth-orbit satellites, for example. Amateurs will undoubtedly continue to advance the art and science of radio - but only if adequate spectrum resources are kept available for their use. One way for Ofcom to intervene in promoting innovation is by publicising opportunities for experimenting with radio which are open to licensed amateurs.

But as we note elsewhere in our response to this consultation, it is not appropriate to allow business firms to use the Amateur Service's radio bands for equipment testing, even if some of their employees are licensed amateurs. Rather, a separate framework is needed for business R&D. ComReg in Ireland recently concluded a public consultation on the Trialling of Wireless Services and Technologies and "now intends to proceed swiftly with the introduction, early in 2005, of a new licensing regime for radio service and technology trials which will bring Ireland to the forefront as an ideal location for research and development."[32]

An interesting aspect of ComReg's scheme is that it does not involve a new allocation of frequencies. Rather, ComReg will "Encourage test and development activities in all available frequency bands..." and "Investigate the possibility of exempting from licensing, tests involving very low emissions where the risk of interference is

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[31] A tutorial presented at the International Symposium on Advanced Radio Technologies (Boulder, Colorado, USA, 2 February 2004) - http://www.its.bldrdoc.gov/meetings/art/art04/slides04/mat_r/tutorial_b_slides.pdf

[32] "Response to Consultation: Opportunities for Trialling Wireless Services and Technologies in Ireland," ComReg Document 04/115, 29 November 2004 - http://www.comreg.ie/_fileupload/publications/ComReg04115.pdf

negligible." We recommend that Ofcom should consider a similar policy, harmonised with ComReg's.

Question 17

Is Ofcom's approach of not intervening to mandate entitlements in time appropriate?

Ofcom should mandate cognitive access by short-range devices in the bands available to license holders. Existing license holders do not have monopoly rights over all use of the bands in which they are licensed and Ofcom certainly should not confer such rights now if it seeks greater flexibility and more benefits to society from fuller use of the spectrum resource. As the consultation document notes on page 39, "*De-facto* entitlements to transmit in spectrum licensed to others already exist" (although *de jure* entitlements do not). Licences only confer the right to utilise a set of frequencies without harmful interference in certain locations for certain purposes. If the definition of purpose is broadened or cancelled, it does not logically follow that license holders thereby gain the right to prevent others from using non-interfering technologies in the same band. The right of non-interference should be preserved - at least until Ofcom authorises "interference rights" trading - but excluding license exempt activities from a licensed band is not necessary to achieve non-interference. On the contrary, we encourage Ofcom to propose a "floor" or "floors" for licensed emissions, below which no license is needed for low-power/short-range uses ("underlays"). If a UWB "mask" is approved, it might become the initial basis for such a floor.

However, the way Question 17 is framed obscures an issue which we find profoundly troubling - Ofcom's proposal to *forbid* cognitive access by license exempt devices.

Indeed, we found the consultation paper's discussion of "cognitive radio" (CR) generally unsatisfactory. The main problem is a lack of recognition that CR is an evolving, composite feature set which can be exercised in quite different modes - for the sake of clarity, we can call them "selfish" and "collaborative."

Some components of CR are already in wide use in the license exempt bands, having been incorporated into technical standards and professionally endorsed "best practices."[33] Some are even mandated by UK, EU and ITU regulations. Many seem vital for the further growth of services in unlicensed bands. The current draft of the consultation paper is not clear about which CR implementations Ofcom wants to forbid. If it is the reliability or effectiveness of CR implementations that is the issue, then by all means encourage testing and set clear criteria for type acceptance. We urge Ofcom to authorise cognitive access, for a test period lasting 6 months at least, in at least one of the licensed bands "well-suited to cognitive radio... such as some emergency service bands." (Pages 40-41) That is the best way to determine whether harmful interference to license holders is likely or not in practice.

The subject of CR is introduced on page 5 with a warning: "We see many technical and commercial problems with cognitive radio which might result in interference and so do not propose to make it license exempt." The lengthier discussion of CR in **Section 5.3.2** (pages 39-41) makes it clear that OFCOM is worried mainly about the

[33] "WLANs already incorporate essential CR features such as dynamic frequency selection and transmit power control," notes Patrick Mannion in "Sharing spectrum the smarter way," *Electronic Engineering Times*, 5 April 2004 - http://www.eet.com/showArticle.jhtml?articleID=18700443.

"hidden terminal problem" and is not sure there are effective technical solutions. Unless persuaded by comments gathered in this consultation, the regulator may "indicate" to license holders that CR should only be permitted in "bands with single owners," preferably those "which have a high peak-to-average usage such as some emergency service bands... However, under trading legislation we will allow license holders to agree cognitive access with third parties if they wish to do so."

We are baffled by Ofcom's assessment of CR. Apparently the regulator sees in it *only* "technical and commercial problems" and not the benefits of radios which monitor the spectrum before transmitting to verify channel vacancy, and which adapt their emissions to the actual signal environment. These features are ignored as the consultation document attempts to reduce CR to "frequency agile radios."[34]

CR aims to make the operational behaviour of radios smarter. In addition to real-time monitoring, it is possible to use the radio's memory of previous monitoring to discover patterns of frequency availability.[35] In addition, feedback from terminals that are part of the CR's own network can be used for power management, so that the CR always uses the least power necessary for a link. Location-awareness (based on Global Positioning Satellites or similar systems) is factored into some mobile CR projects. The DARPA XG project (see http://www.darpa.mil/ato/programs/XG/) plans to include lookup tables of frequency assignments in the radio's memory, along with band use policy rules promulgated by national and international regulatory authorities, which can be automatically invoked through location awareness and waveform recognition. Other models under development for the US military aspire to "know" what signals interest the user and execute "model based reasoning about user needs, local content and environmental context" to find such signals.[36]

Physical constraints limit what is possible to achieve with CR in practice (cost, processing time, hardware weight, battery capacity, etc.). Some elements of the feature set are unproven and futuristic. But others are reliable, low-cost and already widely deployed. CR is an evolving cluster of capabilities that will expand and improve through time.

In light of CR's diverse ambitions, we find the definition provided in the consultation document's **Glossary** inadequate:

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[34] The first paragraph of **Section 5.3.2** reads: "Radios can now be implemented which can scan multiple frequency bands, spot an unused band, transmit on this band and then move to a different band. Such radios have been termed software-defined radios (SDR) or cognitive radios. Strictly they only need be frequency agile radios..." However, frequency agility is not specific to CR, being found in cordless phones, Citizens Band radios, amateur radio stations, land mobile "Business Radio" terminals, etc. Ofcom would face a mass rebellion if it tried to implement the restrictions proposed for CR on all frequency agile radios.

[35] The **Glossary** definition of CR may give the impression that such radios normally exploit millisecond pauses in channels that are heavily used - a context where it is clearly difficult to predict when the licence holder will revisit the channel and implying a high probability of co-channel interference. In fact, as noted in **Annex I: Measurement Data** (page 74 of the consultation document), "large parts of the spectrum...are little used." To conserve battery power and processing time, cognitive radios are often biased to select the frequencies least occupied by the primary assignees.

[36] "SDR Technology Implementation for the Cognitive Radio" by Bruce Fette, General Dynamics Decision Systems, 16 May 2003 - http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6515287635

> *"**Cognitive radio** - A radio which can sense when a piece of spectrum is not being used, adapt itself to fit the spectrum, transmit briefly and then move onto the next free piece of spectrum."* (Page 78)

Too little of the CR feature set is represented in that definition to express the goal of CR development, which is to automate the avoidance of interference while maximising spectrum utilisation. In addition, the scenario implied by the definition is an autonomous CR transceiver operating in "selfish" mode. In fact, CR can be even more effective in "collaborative" mode, either as part of a network or by automatically negotiating dynamic frequency-sharing and interference-reducing arrangements with nearby devices that are also adaptive.

The analysis produced last year for Ofcom entitled "Evaluating spectrum percentage occupancy in license-exempt allocations"[37] highlighted the co-existence problems of WLANs, Bluetooth devices, and other radiators in the 2.4 GHz band. The increasing density of overlapping signals in that band makes mutual interference all too common. Another growing problem is portable devices with more than one type of radio capability - Wi-Fi and Bluetooth, for example - which contend with each other when co-located. Laptop computers, personal digital assistants (PDAs) and mobile phone handsets contain such pairings.

To solve such problems, a growing number of proposals - 29 at latest count, mostly exploiting CR techniques, have been submitted to the IEEE 802.15.2 Subgroup on Coexistence.[38] "Adaptive Frequency Hopping" (AFH) was approved by the IEEE in 2001 as a "recommended practice" for interference mitigation and a few months later, the Federal Communication Commission modified its rules to allow AFH in the US's license exempt bands.

Europe has also authorised CR techniques for use in license exempt bands. According to the CEPT Electronic Communications Committee's "Strategic Plans for the Future Use of the Frequency Bands 862-870 MHz and 2400-2483.5 MHz for Short Range Devices" (Helsinki, May 2002)[39]:

> "Due to the anticipated rapid growth of [wideband transmission systems in license exempt spectrum] the use of certain interference mitigation techniques will become inevitable to allow all the services and applications to co-exist within the band... The possible mitigation techniques could include:
>
> a) Dynamic Frequency Selection (DFS)
> b) Adaptive frequency hopping techniques where frequency hopping systems avoid channels identified as occupied...
> d) Co-existence protocols for transmitters associated with receivers based on 'listen before talk'... [etc.]
>
> "The frequency band 2400-2483.5 MHz is used for Short Range Devices on a world wide basis and it is important that the use of the band is harmonised within Europe in principle without national restrictions. It is also important that world wide harmonisation is achieved as far as possible in order to achieve spectrum access for

[37] Final report by Aegis Systems and Transfinite Systems, 7 July 2004, online at http://www.ofcom.org.uk/research/industry_market_research/technology_research/ses/ses2003-04/ay4529/perc_ocp_lisc.pdf

[38] See http://grouper.ieee.org/groups/802/15/pub/TG2-Coexistence-Mechanisms.html for a current list.

[39] http://www.ero.dk/456A011D-C772-4306-8B08-78BF1949A03E.

> new innovative services in Europe and the detailed regulation of the band should therefore seek alignment with regulation in other regions of the world."

Finally, we must note that the UK government approved ITU-R Resolution 229, which was adopted at the World Radio Conference in 2003[40] opening spectrum in the 5GHz band for WLANs that are license exempt in most parts of the world, on condition that the WLANs employ "dynamic frequency selection" (DFS).[41] The use of DFS is mandated by ERC Decisions (99)23 and (04)08.[42]

We have probably delved too deeply into this topic, but we wanted to demonstrate how extensively CR capabilities are already established, approved and even mandated in UK, European and international regulations. It seems obvious to us that license exempt devices should be allowed - even encouraged - to learn whether a channel is occupied before they transmit, and to modify their transmission patterns dynamically to avoid channels in use by other devices. What benefit is there in forbidding these (CR) capabilities? How then will the UK implement the ERC Decisions for the 5GHz band, where there will be sharing by licensed and license-exempt users, with the license-exempt users required to use CR techniques?

We cannot leave this topic without commenting on the "hidden terminal problem" which is given such prominence in the consultation document. If a transmitter is located behind an obstruction, the signals' shadow loss could be as much as 40 dB. The fear expressed by Ofcom is that a CR located in the radio shadow would be unable to detect the transmitter's signal, causing it to treat the channel as empty and thus available for use by the CR. But note that it is possible to detect the presence of signals which are much too weak to decode for their content. There are even receiver designs which make it possible to detect signals below the noise floor. Ultra-WideBand (UWB) devices have this capability, as do "cyclostationary" feature detectors. The sensitivity of feature detectors can be made much greater than the shadowing losses caused by environmental obstructions:

> "Most applications of signal detection in commercial practice are based on 'radiometric detectors' which only function if the signal is greater than the noise level in the receiver system. However, in the past decade information has become available about an alternative technology called cyclostationary detectors or feature

[40] "Use of the bands 5150-5250, 5250-5350 MHz and 5470-5725 MHz by the mobile service for the implementation of Wireless Access Systems including Radio Local Area Networks," ITU-R Resolution 229, (Geneva, 2003) - http://www.med.govt.nz/rsm/planning/srd/discussion/discussion-14.html.

[41] DFS is a Cognitive Radio technique developed by CEPT which "provides a detection mechanism to avoid co-frequency operation with radar systems... [and] a spread of loading of the RLAN use across the available spectrum to facilitate sharing with satellite services." Its workings are described in "Candidate Harmonized European Standard (Telecommunications series) ETSI EN 301 893 V1.2.3 - Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive," 1 August 2003 - http://webapp.etsi.org/exchangefolder/en_301893v010203p.pdf

[42] "ERC Decision of 29 November 1999 on the harmonised frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs)," (ERC/DEC/(99)23) ECC - http://europa.eu.int/information_society/policy/radio_spectrum/docs/current/mandates/rscom0341_mandate_rlan.pdf; "Decision of 09 July 2004 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs), " (ECC/DEC/(04)08). See also "Draft ECC final report on 5 GHz RLANs," Radio Spectrum Committee, RSCOM04-50Rev1 (15 September 2004) - http://forum.europa.eu.int/Public/irc/infso/radiospectrum/library?l=/publicsdocumentss2004/rsc9/rscom04-50rev1_rlanspdf/_EN_1.0_&a=d

> detectors which use longer sensing times and internal computation to achieve signal sensitivities below the noise level for signals of known format... In practice, processing gains of 30-40 dB can be achieved with computation resources typical of today's microprocessors. With such a detector capable of receiving signals more than 30 dB below the noise floor the hidden node problem that might result in missing the presence of a signal becomes much less likely than with radiometric detectors."[43]

[43] "ET Docket No. 03-108 and ET Docket No. 00-47 - Notice of Proposed Rule Making and Order: In the Matter of Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies; Authorization and Use of Software Defined Radios," US Federal Communications Commission, Office of Engineering Technology, 17 December 2003 (paragraph 25). See also "Signal Interception: A Unifying Theoretical Framework for Feature Detection" by W. A. Gardner, *IEEE Transactions on Communications*, vol. 36, no. 8 (August 1988) and "Implementation Issues in Spectrum Sensing for Cognitive Radios" by Danijela Cabric, Shridhar Mubaraq Mishra, and Robert W. Brodersen, Berkeley Wireless Research Center, University of California at Berkeley, paper presented at the Asilomar Conference on Signals, Systems, and Computers, 7-10 November 2004 - http://bwrc.eecs.berkeley.edu/Publications/2004/PRESENTATIONS/dc.smm.asilomar/asilomar_paper_danijela.pdf.

Summary and Conclusion

Open Spectrum UK is grateful for the opportunity to contribute to Ofcom's Spectrum Framework Review. We hope our comments have been found helpful, along with our recommendations summarized below.

We applaud Ofcom's treatment of license-exempt access as not just an exception to the norm of licensing, but as a "statutory obligation" and one of three basic approaches to spectrum management, alongside "market-based" and "command and control." It is an oversimplification, of course, to equate "market-based" with tradable licences. Market forces promote efficiency and flexible use in the license-exempt bands even more than in licensed bands – but there it is the market for equipment rather than for frequencies which drives the process.

We were not convinced by the arguments raised against license-exempt "cognitive access," but Ofcom's support for additional spectrum for license-exempt activities "as needed" is very positive. At the same time, we hope that serious consideration will be given to our suggestions that licensing need not be the "default" policy for bands above 30GHz and that the licensing of receivers is unnecessary. We would refrain from putting a ceiling on the amount of spectrum to be made available to license exempt activities as there are policy justifications for being generous with exemptions, which are just as important to consider as estimated need. In light of the EU's licensing directive and framework for electronic communication - both of which give preference to open market access or general authorisations instead of to individual licences - the UK's basic wireless telegraphy laws might also need re-examination.

In the final analysis we regard this consultation as the start of an intensified dialogue between spectrum managers and stakeholders on the strategic aims of the spectrum policy framework. We encourage Ofcom to formalise this dialogue by establishing a "Wireless Regulation Forum" to act as a channel of communication with all stakeholders – not just with license holders, but with the license-exempt community and with the end-users of radio communication services and others. The signatories identified below would all welcome further discussions with Ofcom's spectrum team on any aspect of this statement which may need clarification or debate.

Recommendations

- Amend the UK's wireless telegraphy law to recognise general authorisation as an option distinct from both license exemption and individual licences; and to recognise license exempt activities as normal rather than as exceptional. The licensing of receive-only terminals should be discontinued.

- "Spectrum should be made available for license-exempt use where there is a low probability of congestion," Ofcom says. We recommend that as a general policy, not just for rural areas.

- Avoid the words "maximum" and "ceiling" to describe preliminary estimates of the bandwidth needed for license-exempt activities.

- Ofcom should seriously consider having licensing not be the default policy for bands above 30GHz.

- In the near future, Ofcom should adopt a formal procedure for periodically assessing the need for additional spectrum for license-exempt uses. The procedure might include technical studies designed to measure spectrum occupancy; low-flying aerial surveys; public consultations on the need to change current band allocations or power limits; annual market surveys; etc.

- Consider raising the power output limit to 200mW for license-exempt WLANs in the 2.4GHz band, and to 1 watt in the 5.8GHz band, as Singapore recently did – and not just in rural areas.

- Designate different bands for different types of license-exempt devices - perhaps through type acceptance - while recognising the possibility of special compatibilities among dissimilar technologies and allowing for innovations which stretch the purpose of a specific band.

- Re-examine the rules for receiver performance to see what can be done to improve selectivity and interference-resistance, without putting unreasonable cost or skill burdens on receiver users.

- Instead of putting the proposed Community Audio Distribution System in the 27MHz Citizens Band, authorise it as a subcarrier service which FM broadcasters can add to their existing signal for listeners to decode with inexpensive add-on devices.

- Coordinate with ComReg in Ireland to streamline the issuance of experimental and test licences for new technologies in "all available bands;" Consider de-licensing tests and experiments when the interference risk is negligible.

- Protect the non-commercial character of amateur radio and publicize it as a way to experiment with radio.

- Licensed and license-exempt services must find ways to coexist in additional frequency bands. Nevertheless, we support Ofcom's effort to find additional contiguous, exclusive spectrum for license-exempt activities around 5GHz.

- Ofcom should mandate cognitive access by short-range devices in the bands available to license holders, and should not forbid the use of cognitive techniques by license-exempt devices. Define power "floors" in licensed bands below which no license is needed. The Ultra-WideBand "mask" might be suitable as an initial floor.

- Software-Defined Radio (SDR) and Cognitive Radio (CR) should be considered in more depth in Ofcom's revised Spectrum Framework Review document, and not only as threats. SDRs should not be excluded from license-exempt use. Ofcom should organise a public consultation on the regulation of SDR.

- Publishing a "compendium of issues" would help educate the public and increase the transparency of regulatory activities.

- Ofcom should establish a "Wireless Regulation Forum" to act as a channel of communication with all stakeholders, not just license holders.

Signatories

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Submission

Submitted to Ofcom by John Wilson on behalf of Open Spectrum UK
15 February 2005