Digital Dividend: Geolocation for Cognitive Access

A discussion on using geolocation to enable licence-exempt access to the interleaved spectrum

Discussion document

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Section 1

Executive summary

Background

1.1 Since its launch in 2005, our Digital Dividend Review (DDR) has considered how to make the spectrum freed up by digital switchover (DSO) available for new uses.[1] This includes the capacity available within the spectrum that will be retained to carry the six digital terrestrial television (DTT) multiplexes after DSO. This is known as interleaved spectrum because not all this spectrum in any particular location will be used for DTT and so is available for other services on a shared (or interleaved) basis.

1.2 In our statement of 13 December 2007 on our approach to awarding the digital dividend,[2] we considered the use of interleaved spectrum by licence-exempt cognitive applications (i.e. those exempted from the need to be licensed under the Wireless Telegraphy Act 2006[3]). We concluded that we should allow cognitive access as long as we were satisfied that it would not cause harmful interference to licensed uses, including DTT and programme-making and special events (PMSE). This could potentially bring substantial benefits to citizens and consumers in the form of new devices and services.

1.3 We published a consultation on proposed parameters for licence-exempt cognitive devices using interleaved spectrum on 16 February 2009.[4] In a subsequent statement published on 1 July 2009[5] we concluded that cognitive devices should either sense the presence of other signals or make use of a geolocation database to determine which spectrum was unused in the vicinity. In that statement we provisionally concluded on the parameters needed for sensing but noted that further discussion would be needed as to how a geolocation database might operate. This discussion document is intended to stimulate and inform such discussion.

Cognitive access to interleaved spectrum

1.4 Much previous work has assumed that cognitive devices would sense the use of spectrum by monitoring for licensed transmissions and only transmitting if they found none in a particular frequency range. Recent studies have shown however that the signal levels they would need to sense down to, in order to be certain of not causing harmful interference, are extremely low and so alternative approaches are now being considered.

1.5 The most promising alternative to sensing (also known as detection) appears to be geolocation, where cognitive devices measure their location and make use of a "geolocation" database to determine which frequencies they can use at their current location. They are prohibited from transmitting until they have successfully determined from the database which frequencies, if any, they are able to transmit on in their location. In this case parameters such as locational accuracy and frequency of database enquiry are important.

[1] See www.ofcom.org.uk/radiocomms/ddr/ for more information about the DDR, including previous publications.
[2] www.ofcom.org.uk/consult/condocs/ddr/statement/statement.pdf.
[3] www.opsi.gov.uk/acts/acts2006/pdf/ukpga_20060036_en.pdf.
[4] www.ofcom.org.uk/consult/condocs/cognitive/cognitive.pdf.
[5] www.ofcom.org.uk/consult/condocs/cognitive/statement/statement.pdf.

1.6 This discussion document focuses on geolocation and the mechanisms likely to be needed for it to work. It is intended as input to the thinking that is taking place around the world on geolocation rather than as a statement of clear regulatory intent. As such, it is hoped that it will further discussion and speed the development of possible geolocation solutions. It does not seek to change in any way the decisions on general cognitive access and sensing set out in our July 2009 statement.

Key geolocation issues

1.7 We see five key issues to be addressed in developing a geolocation approach.

1.8 *The information to be provided by the device to the database(s)*. We suggest that this be flexible with the device allowed to select from providing only its location through to providing location, locational accuracy, device type and preferences as to the amount of information that it receives. As the device provides additional information the database can tailor its response, in some cases allowing higher power levels. We note that this may require standardisation work around the protocols to be used.

1.9 *The information returned from the database(s) to the device*. We suggest that this should be a list of frequencies and power levels for each geographical pixel or location. Alternatively, if the device has moved to a different country, the database might return the address that the device now needs to send its enquiry to.

1.10 *The frequency of update of the database(s) and hence the periodicity with which devices will need to re-consult*. Because some licensed uses of relevant frequencies might require access at short notice – for example some PMSE users - we suggest that devices be required to recheck the database at least every two hours.

1.11 *The modelling algorithms and device parameters to be used to populate the database(s)*. We make some detailed suggestions as to propagation algorithms, assumed device sensitivity and methodology that would enable the database to derive the list of frequencies that could be available for cognitive devices from the information provided about licensed use.

1.12 *The maintenance of the database(s)*. We note that someone will need to develop and host the database and that costs will be incurred. We seek views as to who should be responsible for the database and on what terms, where the costs might fall and what role it would be appropriate for regulators to play.

Next steps

1.13 This discussion invites responses by 9 February 2010. We will consider any responses we receive and then decide on what to do next.

Section 2

Introduction

2.1 Previous documents have set out in detail the DDR and the issue of licence-exempt cognitive access to interleaved spectrum within this. This discussion document focuses on geolocation as a mechanism for cognitive access.

The need for geolocation

2.2 In our July 2009 statement on cognitive access we noted that there were three mechanisms that could be used by a cognitive device to determine which frequencies it could use to make transmissions: sensing, geolocation and beacon transmission. We concluded that beacon transmission was inferior to the other two approaches and that we would not consider it further. We noted that there were advantages and disadvantages to both sensing and geolocation and at this stage in the development of cognitive devices it was appropriate to allow both to enable device developers to select their preferred approach. We also noted that the parameters necessary for sensing resulted in devices needing to sense down to a very low signal level which might be problematic in the near-term. Hence, we concluded that enabling geolocation was likely to be important for the development and deployment of cognitive devices.

The reason for this discussion document

2.3 Much of the work on cognitive access to date has been on sensing with research only relatively recently moving to geolocation as the difficulties with sensing became increasingly clear. As a result, the body of knowledge around geolocation is less well developed and we felt unable to conclude on appropriate mechanisms at the time of the July 2009 statement. Since that time further work has been undertaken both in the UK and other countries, notably the US. We have monitored and influenced this work and have also held discussions with relevant stakeholders across a wide range of issues. We now believe that it would be helpful to clearly set out the open issues and some of our thinking in these areas. It is quite likely that some of the areas discussed here will be standardised by others, or that manufacturers may adopt proprietary approaches, but we believe that by clarifying and identifying the issues we will be able to assist in the development of a geolocation approach, delivering on our duties to further the interests of citizens and consumers by securing the optimal use of spectrum through encouraging innovation.

Our bias against intervention

2.4 Ofcom has a bias against intervention. We believe that markets generally deliver the best solutions and that intervention is only required where there are clear indications that the market will not do so.

2.5 Our preference, therefore, is for the market (including entities such as standards bodies) to deliver as much as possible of the specification for cognitive devices. This should maximise flexibility and innovation and avoid the regulator preventing desirable outcomes through incorrect or excessive regulation. This preference means that, wherever possible, we will leave standardisation and specification work to the marketplace.

2.6 There may, however, be some areas where regulatory intervention is likely to prove necessary. These might include ensuring the protection of existing licence holders by specifying the maximum probability they can expect to receive harmful interference and in ensuring the ability to change some parameters to provide flexibility of spectrum management. In each case where we suggest that we or other regulatory bodies may have a role we will explain why we believe this may be appropriate.

Key issues to be considered

2.7 Based on previous work and workshops held with key stakeholders we believe that the key issues to be addressed in developing a geolocation approach are:

- The information to be provided by the device to the database[6].
- The information returned from the database to the device.
- The frequency of update of the database and hence the periodicity with which devices will need to reconsult the database.
- The modelling algorithms and device parameters to be used to populate the database.
- The maintenance of the database.

2.8 Each of these issues is considered in turn in this document.

Structure of this document

2.9 This document is structured as follows:

- Section 3 considers the information to be provided by the device to the database.
- Section 4 considers the information returned from the database to the device.
- Section 5 discusses the speed of update of the database and hence the periodicity with which devices will need to reconsult the database.
- Section 6 considers the modelling algorithms and device parameters to be used to populate the database.
- Section 7 considers the maintenance of the database.
- Section 8 outlines the path we propose to follow to maximise the probability of achieving acceptable international harmonisation.
- Section 9 summarises our thinking and sets out next steps.

[6] Note that there could be one or more databases. We address this issue in more detail in later sections and for convenience use the term database in the singular.

Section 3

Information provided to the database

Introduction

3.1 When defining a geolocation approach it is important to define the type and format of information to be exchanged between the devices and the database. This is so that a wide range of devices from different manufacturers can all successfully access the database. This section considers the information to be provided by the device while the next section discusses the information that should be returned to the device.

3.2 In general, detailed specification of parameter values is performed by standards bodies such as the European Telecommunications Standards Institute (ETSI) or the Institute of Electrical and Electronics Engineers (IEEE) and not by regulators. In this document we are seeking to determine appropriate parameters at a relatively high level and would hope that industry would then move to deliver the necessary standards.

Q1: Should we suggest only high level parameters, leaving further work to industry, or should we seek to set out full details of parameters to be exchanged?

Number of databases and general approach

3.3 It is possible to have one or more databases. If there are multiple databases they all need to provide the same guidance to the cognitive device but might do so in different ways.

3.4 One option is to have a single database for the entire country. All cognitive devices consult this database using a pre-defined and standardised message format. The database would be open to all users.

3.5 A second option is to have multiple identical databases. In this case, cognitive devices could select their preferred database but there would be no material difference between them. Apart from an improved resilience there does not seem to be any advantages to this approach from a technical perspective.

3.6 A third option is to have “closed” databases corresponding to different types of devices. For example, a manufacturer of cognitive devices might also establish a database for those devices it had made. Multiple manufacturers might work together to share a single closed database or one manufacturer might “open up” its protocols and database for others to use if they wish.

3.7 The advantage of the closed approach is that an open standard protocol is not required. Instead, the manufacturer can device its own protocol and implement it in the database and the device. The closed database approach has the advantage of avoiding the need for standardisation, potentially being implemented faster and allowing manufacturers to differentiate their devices.

3.8 The disadvantages of the closed approach are the need for each manufacturer to establish and maintain a database, potentially in multiple countries. This might be problematic, for example, if the manufacturer subsequently withdraws its support for cognitive devices. It might also require more regulatory action to “police” multiple different databases.

3.9 We see no reason from a technical perspective to specify a particular approach and note that both can exist in parallel with some manufacturers directing their devices to an "open" database and others delivering a "closed" database.

Q2: Should both closed and open approaches be allowed? Should there be any additional requirements on the providers of closed databases?

Options

3.10 In overview, we see two options for information provision:

- *Location*. The device would provide its location. This would enable it to download only the frequency availability relevant to its current location. The device could provide some information on the accuracy of its location determination[7] or a default level could be assumed.

- *Device type*. Providing information about the type of device, such as the make and model number, might allow information to be returned according to device capabilities. For example, devices which are known to have superior out-of-band emission characteristics might be able to transmit with higher power levels at certain frequencies and/or locations.

3.11 Our initial thinking, based on discussion with stakeholders, is that the requirements on devices should be minimised as far as possible but with flexibility provided. For example, we might allow the following options:

- A device could return its location. If it is able to determine this to an accuracy of better than 100m[8] then no additional information is needed, otherwise it will need to provide the accuracy of its determined location. Available frequencies within a default radius[9] are then provided taking the location accuracy into account.

- The device could opt for the download to be over a different radius from the current location. For example, if the device was aware of its speed of movement it might opt for a small radius in the case it was moving slowly or a larger radius when moving quickly.

- A device could return model identification information. The database could then take into account its known transmission parameters in returning appropriate frequency usability.

3.12 If an open approach was to be adopted then protocols would need to be developed such that the database was able to identify which information was being provided (eg by using a common data format). We would expect these to be developed by standards bodies – for example the IEEE 802.22 is already considering detailed protocols that might be used for cognitive devices providing rural broadband

[7] For some location methods such as GPS devices can determine their location accuracy. For others, such as using W-LANs, the device could be pre-programmed with the known accuracy of its location method. Part of the approval process might be to validate that the device correctly reported its location accuracy as necessary.
[8] This value is based on responses to our cognitive consultation which asked for guidance on appropriate location accuracy.
[9] The default radius would need to strike a balance between being too small, resulting in frequent re-consultation of the database for devices that were moving and too large, resulting in large data transfers taking place, potentially over relatively narrowband channels. Once the data format is agreed further work can determine an appropriate radius.

coverage and it may be that these protocols can be more widely adopted for all cognitive devices.

Section 4

Information returned to the device

Introduction

4.1 The previous section discussed the information to be provided by a device to the database. This section considers the information that should be returned to the device.

4.2 Cognitive devices using geolocation will be prohibited from transmitting until they have successfully communicated with the database and determine which frequencies, if any, are available in their location. They must only transmit on those frequencies and with the associated power levels. If they move outside of the geographical area for which they have frequency information they must re-interrogate the database before transmitting.

Transmitter location or frequency availability?

4.3 A geolocation database could at its simplest return to the device the location of known transmitters in the vicinity. The device could then compute from this the frequency availability. Alternatively, the database itself could compute the frequency availability and return this to the device.

4.4 It seems more appropriate for the database to perform the computations needed to translate the known transmitter location into frequency availability. This is because this computation is complex and relies on many assumptions as to receiver sensitivity, propagation environments, etc as will be discussed further in section 6. Making these calculations within the database ensures that they can be carefully verified and changes made if necessary. If they are implemented in the device there is less ability to verify their correctness and likely no ability to change parameters should it subsequently be determined to be necessary.

4.5 In addition, there seems to be no benefit to performing the calculations within the devices but some potential downsides associated with the need for a relatively powerful processing unit and storage needed to hold terrain databases over large areas.

Q4: Should the translation from transmitter location to frequency availability be performed in the database or in the device?

Form of the information

4.6 The simplest form of information would be to provide a list of frequencies that could be used within each "pixel" (where a pixel would be defined as a square of pre-arranged dimension, eg 100m x 100m). The size of the pixel is a trade-off. Too large a pixel would result in a larger sterilisation than necessary; too small a pixel would result in a larger information transfer to the device than needed. Given that most propagation and terrain databases are not available, or are very expensive, below a resolution of 100m and that wireless microphone use can be in a location with dimensions of less than 100m x 100m we suggest that 100m x 100m pixels are an appropriate compromise.

4.7 Frequency information might be based on a particular bandwidth or alternatively might be provided as a start and end frequency. Again there is a trade-off here. The use of pre-defined bandwidths reduces the information needed to be passed to the device but limits the flexibility to make use of narrower bandwidths, should they become available. We suggest using start and end frequencies in order to maximise flexibility.

4.8 In addition, the maximum transmit power might be provided for each frequency assignment. We believe this to be a valuable addition because:

- It would allow devices to use higher powers in areas where the frequencies were not in use for some distance. This might be valuable in the provision of services such as rural broadband.

- It would allow lower powers to be specified if harmful interference occurred in practice at higher powers, allowing a “fine tuning” of the database over time.

- It would allow different powers to be set for different devices, with those devices having the lowest out-of-band emissions being allowed to use higher power levels in some cases, encouraging better radio design.

4.9 We would expect industry to provide the detailed specifications for this information transfer as needed depending on whether a closed or open database approach was adopted.

Q5: Have we outlined an appropriate information set for the database to provide to the device? Can industry be expected to develop the detailed protocols?

Section 5

Database update frequency and reconsultation

Introduction

5.1 A key issue in implementing a geolocation database is the frequency with which the database should be updated. This will depend on the rate at which the assignments of the licensed users of the spectrum change and the notice that they are able to provide. In general, licensed users would prefer a rapid update as this will provide them with the greatest flexibility to make rapid changes to their assignments. Cognitive device users, however, would prefer updates to be as infrequent as possible to avoid the overheads associated with repeated database access. This section discusses the needs of the licence holders and the implications these may have for cognitive users.

Needs of licence holders

5.2 After DSO, the two major licence holders in the interleaved spectrum considered for cognitive access will be DTT multiplex operators and PMSE users. In general, changes to DTT transmitter parameters will be rare and are known many days in advance. However, PMSE use for devices such as wireless microphones changes much more frequently. Hence, it is the timing requirements of PMSE users that we believe will set the update frequency of the database.

5.3 Information provided to us by JFMG, who currently grant PMSE licences on our behalf, suggests that around 30% of assignments are requested on the day that they are needed. Times between a frequency being requested and its being required can be as little as two hours.

Implications for update frequency

5.4 The manufacturers of cognitive devices have previously suggested that an update period of 24 hours would be helpful. This would allow devices to download the database at the start of the working day, perhaps using a WiFi or similar broadband connection, and then not have to perform further database access during the day. The needs of PMSE users suggest that this will not be viable.

5.5 One solution has been suggested whereby some channels in each location are permanently set aside from cognitive use. When PMSE access is required at short notice these “safe harbour” channels would be preferred allowing a longer update period on the remaining channels[10]. However, PMSE users have indicated that this approach is problematic because most individual wireless microphones only tune over a 16MHz or 24MHz range (albeit collectively they tune across the whole interleaved spectrum) and hence there is a risk that they would not be able to use the safe harbour channels in a given location.

[10] This is an approach adopted by the Federal Communications Commission (FCC) in the US. However, the situation in the US is somewhat different to the UK, with a much greater number of unlicensed microphones in use in the US.

5.6 Our view, based on the needs of PMSE users, is that devices should check the database at least two-hourly if not more frequently. This would imply, for example, that a device that remained in the same position would still need to perform periodic two-hourly checks of the database. If it had not checked the database for over two hours it would not be allowed to transmit.

Q6: Is a two-hourly update frequency an appropriate balance between the needs of licence holders and of cognitive device users?

5.7 An alternative, more flexible approach would be for the database to return a “time validity” along with any request. Initially, this might always be set to a short time period such as two hours. However, if over time it became clear that a safe harbour approach could work, or that a longer time period would provide sufficient protection for licensed users, this could be changed. Although this adds a small amount of complexity it appears to us that it might provide important flexibility.

Q7: Is there benefit to devices receiving a time validity along with any database request and to act accordingly?

5.8 Another approach that has been suggested is to use “push” technology. In this case a cognitive device would register with a database which would proactively send a message to the device if the licensed use in its area changed. However, this requires the device to be permanently connected to the database (likely via the Internet). It does not seem likely that most types of cognitive device would maintain such a connection and we see no clear advantages over periodic re-checking. Hence, we do not believe it appropriate to rely on push technology as part of any regulatory approach.

Q8: What role could push technology play?

Section 6

Populating the database

Introduction

6.1 The input to a geolocation database will typically be a set of transmitter parameters including location, height, transmit power, etc. However, as discussed earlier, the database will supply a list of available frequencies and associated transmit powers to cognitive devices. Hence, a translation must be performed between these two.

6.2 It is clearly critical that this translation is performed appropriately. If it is not then there is a risk either of harmful interference occurring to licensed users or of the cognitive devices having access to the spectrum limited unnecessarily. There are many choices to be made in performing this translation, such as the probability of harmful interference. Licence holders might be expected to prefer a very low probability of harmful interference while cognitive users might prefer a higher level. If setting parameters such as this were left to the many disparate interested parties in the market it is unlikely they would reach agreement. Hence, in the same way that we set the parameters for the use of detection by cognitive devices we believe it is appropriate for us to set the parameters for the translation from transmitter location to allowed cognitive use.

6.3 The approach would differ for DTT and PMSE users and so we suggest separate methodologies for each.

Overview of the translation process

6.4 The database will provide a cognitive device with a maximum power level that it can use in a given location and for a particular frequency range. In arriving at these data, the algorithms employed need to ensure that a device in that location transmitting with the given power level will not cause harmful interference to a licensed user.

6.5 Interference to a licensed use will occur at the receiver of the licensed user. Hence, the algorithms need to understand the possible location of receivers, the level of interfering signal they can tolerate before the interference becomes harmful and the propagation loss between the cognitive device and the receiver. If all these are known perfectly then the cognitive transmit power can readily be determined. Each of these elements is discussed briefly below before being considered in more detail later in this section.

- *Receiver location*. Either the transmitter location or the receiver location of the licence holder might be provided. If the transmitter location is provided then possible receiver locations can then be derived based on the transmitter parameters, the minimum signal needed at the receiver and the propagation conditions. This allows a “contour” to be established around each transmitter in which receivers could be expected to operate.

- *Tolerance to interfering signal*. For receivers to operate without harmful interference they need the wanted signal to exceed the interfering signal by a ratio known as the carrier/interference (C/I) ratio. This differs for different technologies but can generally be characterised in advance using either device specifications or actual measurements. Then, using information on the likely wanted signal strength based on propagation predictions, the maximum interfering signal strength can be predicted.

- *Propagation loss*. Finally, a prediction is required as to the reduction in signal strength as a result of the separation between the cognitive device and the receiver. This can be achieved using propagation modelling tools.

DTT

6.6 Over many years broadcasters have carefully predicted the signal levels that will be received from their transmitter networks and have refined and validated these predictions. This information is held by Arqiva, which conducts the modelling on behalf of the broadcasters. There should be little difficulty in providing such signal strength information to the database. This implies that the database will not need to perform propagation modelling on behalf of DTT.

6.7 In previous consultations and statements we have reported on measurements that have determined the necessary C/I ratio for DTT. We have concluded that devices can operate with 20dB for co-channel interference and -30dB on adjacent channels.

6.8 Regarding co-channel interference, the cognitive device cannot take up the entire 20dB ratio as this would then not allow for other forms of noise and interference. General engineering rules suggest allowing a margin of around 6-10dB such that the interference does not materially degrade this margin. Also, since there might be co-channel and adjacent channel interference present simultaneously, the allowed levels on each need to be reduced by 3dB to ensure the combined effects are not problematic. Hence, taking a conservative approach, we believe that the modelling should not allow interference from a cognitive device to a DTT receiver at a level of about 33dB C/I (ie the cognitive signal should be at least 33dB below the received DTT signal).

6.9 A similar approach is needed to set the adjacent channel C/I ratio. Adding in the same margins increases the ratio to -17dB C/I (ie the cognitive signal must be no more than 17dB above the received DTT signal on the adjacent channel).

6.10 Making use of the existing DTT signal level predictions and the assumptions above of 33dB C/I co-channel and -17dB C/I adjacent channel for DTT receiver performance should be sufficient to enable the database to calculate the associated cognitive transmit powers.

PMSE

6.11 PMSE transmitters and receivers are typically close by in indoor locations but can be separated by kilometres at outdoor events.

6.12 The signal strength at, and location of, receivers will depend upon:

- The transmitter power.
- The nature of use (eg within a theatre).
- Whether directional antennas are used to extend the range of a link.
- The height of the transmitter and receiver.

6.13 Further discussion with the PMSE community is needed to determine the most appropriate way in which data can be provided to the database, particularly as there is currently no single source of information – which would need to be dynamic – about the location of transmitters.

6.14 If this can be addressed, we suggest that free-space propagation modelling be used to predict the received signal level. This will generally reflect the real-world case where PMSE transmitter and receiver have a line-of-sight between each other and will also ensure conservative predictions that will provide additional protection to PMSE users. Where the PMSE use is indoors but the cognitive devices are outside of the building we recommend assuming a 20dB building penetration loss. We accept that this may be overly conservative in some cases and we could revisit this in future as experience is gained with cognitive operation, modifying the rules for populating the database if appropriate.

6.15 In our cognitive statement we noted that most PMSE equipment was operated at signal levels of above -67dBm. While the equipment was capable of operation at much lower levels, using -67dBm provided an adequate margin to ensure a reliable link. However, we accepted that there were some cases where levels as low as -77dBm or even lower were used and suggest that -77dBm be used to determine the limit of PMSE coverage for the purposes of the geolocation database. Hence, using the combination of transmitter power, free space path loss, building penetration (where appropriate) and a minimum signal level of -77dBm we can determine the location and predicted signal strength of PMSE receivers.

6.16 In our statement we suggested that PMSE devices would need a minimum of 25dB C/I for co-channel interference and up to -70dB for channels separated by at least 4MHz. Using the same approach as for DTT this allows us to determine the maximum interference levels as 38dB co-channel and -55dB adjacent channel. These levels can then be used to determine the signal level that a cognitive device could generate.

Q10: Do you have any comments on the suggested approach to implementing the database for PMSE?

Propagation from cognitive devices

6.17 With the information described above a modelling tool could determine the possible location of any licensed receivers (DTT and PMSE), the signal level they would likely experience and as a result derive the maximum signal strength allowed from a cognitive device. The final stage in the process would be to translate this into an allowed cognitive transmit power for a given location. This could be achieved using a propagation model that predicts the difference in signal level between that transmitted by the cognitive device and that received by the licensed device.

6.18 It is anticipated that cognitive devices will generally be operated by users at street level in a similar manner to mobile phones although until the applications that cognitive devices are used for becomes clear this cannot be fully understood. The receivers of licensed users will also be at relatively low levels – PMSE receivers might be 1-2m above ground level for applications such as news gathering, around 6m in studio applications where they are on a gantry and perhaps 10-20m in some outdoor locations. TV receivers might be around 10m above ground level. However, most propagation models predict the signal level between a relatively high transmitter (eg 20m or more above ground level) and a low level receiver. Hence, most existing propagation models are inappropriate for determining the propagation loss between a cognitive device and licensed receiver.

6.19 We became aware of the lack of available model for "terminals of low height" some years ago and conducted research in this area[11]. This led to a suggested model as set out in section 4.8 of that report. The model comprises two prediction elements: one for line-of-sight (LOS) and one for non-line-of-sight (NLOS) and an associated distance below which the LOS model is used and above which the NLOS model is used.

6.20 One of the key parameters for the model is the percentage of locations at which the transmission loss is less than predicted. Where this occurs there is some chance that harmful interference will take place since the signal from the cognitive device will be stronger than the threshold assumed. However, even in this case harmful interference is still unlikely since there would need to be a licensed receiver actually in that location operating close to its minimum C/I ratio with its antenna oriented such that it received the interfering signal strongly. It is not possible to definitely determine the likelihood of harmful interference where the transmission loss is less than predicted since this depends on real-world geometries and deployment patterns.

6.21 In our previous consultation on detection for cognitive access we concluded that harmful interference probabilities should be no more than 0.6% in order that the benefits of cognitive access were greater than the potential loss of value to users of licensed systems (and we proposed levels that would result in a harmful interference probability in the region of 0.05%). However, with geolocation there is the possibility of subsequently altering the level should harmful interference materialise, whereas this is not possible with cognitive devices based on detection. This suggests that we can be somewhat less conservative with geolocation as long as the mechanisms exist for rapidly changing the level should evidence emerge that this is appropriate.

6.22 If we were to adopt a level of 1% then in practice this would be likely to result in an harmful interference probability below the 0.6% level computed above (given that the receiver needs to be turned on, etc). If we were to adopt a level of 0.1% then this would likely result in a harmful interference probability of lower than the 0.05% calculated for detection. Hence, the value should lie between 0.1% and 1%. The differences in signal strength in these values are only around 1dB below approximately 1km and 5dB above approximately 2km, but much more substantial (around 50dB) in the region between 1km and 2km. The practical implications of this will, in many cases, increase the coordination distance from 1km from the nearest receiver to 2km.

6.23 In order to align geolocation with detection we suggest using a 0.1% level. This implies that there is a very low probability that the transmission loss will be lower and hence the interference level higher than expected. In most cases the converse will be true and the interference levels will be substantially lower than predicted.

6.24 We suggest that the building separation distance in the model be set to 50m and for simplicity that the transition distance between models be set to 0. In this case, the model becomes:

- $L_{los} = a + 20\log\left(\frac{d}{1000}\right)$

[11] http://www.ofcom.org.uk/research/technology/research/prop/low/

- $L_{nlos} = b + 40\log\left(\frac{d}{1000}\right)$

where d is the distance in metres between the cognitive device and licensed receiver while parameters a and b are frequency dependent as set out in the table below. The breakpoint distance is 2,100m – below this distance the LOS equation applies while above this distance the NLOS equation applies.

Table 1. Modelling values for propagation from cognitive devices

	Frequency (MHz)		
	400	*600*	*800*
a	73.9	77.4	79.9
b	111.7	116.8	120.5

Allowing for multiple devices

6.25 If there were multiple devices within the same pixel this could raise the interference to licensed users. For example, if there were two devices, equidistant from the licensed receiver and both transmitting simultaneously at their full allowed power levels then the interference could be 3dB higher than caused by one device.

6.26 At present, there is not a good understanding of the likely density of cognitive devices. Even if there are multiple devices in the same area they will likely not all be transmitting simultaneously – and indeed if multiple devices tried to transmit at the same time on the same frequency they would likely interfere with each other.

6.27 Experience of modelling for ultra wideband (UWB) has also demonstrated that it is almost always the device closest to the licensed receiver that dominates the interference, with other devices making little difference to the overall level. We anticipate that this is likely to be the case for cognitive devices too.

6.28 Hence, at this stage, we do not see the need to make any allowance for multiple devices. However, should there be evidence that multiple devices might be problematic, we would take appropriate action. The evidence might be based on modelling as the number of device in use becomes apparent or based on actual cases of harmful interference. The action would likely be a reduction in the power levels allowed for cognitive devices based on changing the C/I values required by licensed receivers in the model.

Practicalities of modelling

6.29 The approach we have suggested here has the potential to be computationally intensive. For every pixel in the UK (of which there would be approximately 245 million if the pixel size were 100m x 100m) it would be necessary to scan every frequency (of which there might be around 1,200 if, for example, a channel size of 200kHz were adopted). At each pixel/frequency point the model would need to “place” a cognitive device and determine the maximum power it could operate without causing harmful interference by modelling outwards in increasing radius circles until the signal level from the cognitive device became insignificant or a victim receiver were found. This modelling process might need to be re-run every time there was a change to the database (for example every two hours). If the modelling itself was time-consuming this might delay the speed with which the database could be updated and hence require the cognitive devices to check more frequently.

6.30 In practice, there might be many design principles that could reduce the computation work required. A simple check could be run to determine those pixels affected by any changes to the database and modelling only performed for these – potentially reducing the number of pixels from millions to thousands. Predicted signal strength maps for the cognitive devices from each pixel could be pre-calculated and stored such that they only need to recalled from memory. Additionally, parallel processing could be adopted since the calculation for each pixel can be conducted independently of the calculation for any other pixel.

6.31 Using these and other approaches we believe that a database could be implemented that could re-compute its contents in a matter of a few minutes.

Q11: Do you believe it is practical to implement such a database?

Section 7

Database maintenance

Introduction

7.1 Implementing and operating one or more databases will require resources. In addition, it may need policing for accuracy. This section discusses where the costs and responsibilities for operating a database might best reside.

Database ownership

7.2 Computation resources will be required to host the database. The host must be highly reliable since database failure would result in cognitive devices being unable to work. It must have sufficient capacity to accommodate what may eventually become millions of requests per hour. It must also be able to re-compute the data sufficiently rapidly as discussed in the previous section. The ownership issues differ depending on whether an open or closed database approach is adopted.

Open database

7.3 Previously some organisations have indicated that they might be prepared to host such a database at no cost. These organisations have been proponents of cognitive access and it might be expected that they indicated this willingness in order to facilitate the emergence of cognitive devices. However, such indications cannot be relied upon at this stage and it may be that nobody is prepared to either offer the service or pay the cost of hosting the database. It may also prove inappropriate for an interested party to provide the database as they might subsequently require certain conditions of access, disadvantaging other stakeholders or users.

Q12: Is it appropriate for third parties to host the database? If so should there be any constraints? If not, who should host the database instead?

Closed database

7.4 In the case of a closed database most of these issues do not arise. By definition the database is owned and funded by an entity that has decided to take on this responsibility.

Pricing and cost recovery

7.5 Funding issues may arise in connection with the database. These might include the cost of establishing and hosting the database and the costs incurred (eg by licence holders) in updating the database with new transmitter locations. Under some scenarios it may be that the database is provided at no cost, licence holders update the database at their own cost and hence funding does not need to be considered. Under others external sources of funding will be needed.

7.6 In the event we needed to play a regulatory role in funding considerations, we would probably start with the six principles of pricing and cost recovery developed by Oftel in the context of number portability, endorsed by the Monopolies and Mergers

Commission[12] and subsequently used by us in analysing various pricing issues[13]. The principles are:

7.7 The principles are:

i) *Cost causation*: costs should be recovered from those whose actions cause the costs to be incurred;

ii) *Cost minimisation*: the mechanism for cost recovery should ensure that there are strong incentives to minimise costs;

iii) *Effective competition*: the mechanism for cost recovery should not undermine or weaken the pressures for effective competition;

iv) *Reciprocity*: where services are provided reciprocally, charges should also be reciprocal;

v) *Distribution of benefits*: costs should be recovered from the beneficiaries especially where there are externalities; and

vi) *Practicability*: the mechanism for cost recovery needs to be practicable and relatively easy to implement.

7.8 The application of any one of these principles to the relevant circumstances can sometimes point in a different direction to other principles. But the set of principles provides a framework to identify such trade-offs and to facilitate the use of judgement to strike an appropriate balance in reaching conclusions.

7.9 An initial assessment against these principles would suggest that:

i) *Cost causation*: the costs are caused by the implementation of cognitive access, suggesting these costs should fall on those benefiting from cognitive access which might include users of cognitive devices, manufacturers of cognitive devices and those offering services to cognitive device users;

ii) *Cost minimisation*: this would suggest that the approach should require those providing information to the database to seek the lowest cost means to do so and those running the database should seek to reduce their costs;

iii) *Effective competition*: this may have limited relevance in the case of cognitive access, with the exception of possible monopoly issues around database management noted above;

iv) *Reciprocity*: this does not appear relevant in this case;

v) *Distribution of benefits*: this appears to lead to the same implications as cost causation in this case.

[12] Telephone Number Portability: A Report on a reference under s13 of the Telecommunications Act 1984 (MMC, 1995):
http://www.competition-commission.org.uk/rep_pub/reports/1995/374telephone.htm#full

[13] See for example: 'Determination under Section 190 of the Communications Act and Direction under Regulation 6(6) of the Telecommunications (Interconnection) Regulations 1997 for resolving a dispute between C&W and T-Mobile about mobile termination rates'

vi) *Practicability*: this may be a very significant issue in this case since practically recovering costs from potentially millions of cognitive device users could be problematic.

7.10 Directly charging the users of cognitive devices each time they used the device or even an annual fee would likely be contrary to the principle of practicability. While possible, the collection of multiple small payments might have a significant overhead. An alternative revenue source would be to charge a royalty on each device sold, possibly collected by the manufacturer and then passed to the database owner or regulator. This would raise a great many difficulties, not least of enforceability, particularly across multiple countries. Further, setting the correct fee level when the market for cognitive devices is unknown would be difficult. Another option would be for Government (perhaps via the regulator) to meet any costs. While practical this does not meet the requirements of the principle of cost causation.

7.11 At present there does not appear to be any simple solution to costs that meets all the principles. We welcome debate on the issue.

Q13: How can any costs best be met?

Provision of information to the database

7.12 Information about licence holders' transmitter locations will need to be provided to the database owner or owners each time these change. If there is more than one database it might be appropriate for information to be provided to a nominated "lead" database which then distributes this information to all other databases.

7.13 We welcome views from licence holders (principally DTT multiplex providers and PMSE users) as to the complexities and costs of providing such access such that, in due course and if appropriate, we could produce an impact assessment setting out the expected costs and benefits of regulatory action in support of introducing a geolocation database.

Q14: What are the difficulties and expected costs to licence holders in providing the necessary information to the database? Could this information be provided in any other way?

Policing the database

7.14 Anyone operating a database would be expected to do so responsibly, correctly implementing rules and cooperating with the regulator as required. If the rules for populating the database are clearly defined and correctly implemented then the database will be free of errors and will not require any regulatory intervention. However, if stakeholders notified the regulator of harmful interference that suggested there were material problems with the accuracy of the data then it would remain the regulator's responsibility to investigate these. We would act in a manner appropriate to the problem.

7.15 If there were problems of harmful interference, the provider of the database would be expected to cooperate with the regulator in using the database to determine why the harmful interference occurred. This might include providing an audit trail of database requests in the vicinity or making use of the modelling tool to analyse possible scenarios. If, as a result, the regulator determined that different access rules were required the database owner would be expected to implement these without delay.

Section 8

International harmonisation

Introduction

8.1 It would be beneficial for a similar database approach to be adopted globally. This would allow cognitive devices to roam from one country to another and for economies of scale to be achieved in the manufacture of such devices. This section considers how a geolocation approach might work across multiple countries and the steps that might be followed to achieve harmonisation.

Enabling geolocation across multiple countries

8.2 One approach to geolocation across multiple countries would be to have a single global database. However, we do not believe this to be practical. It would be complex and expensive to develop and host and would effectively reduce the ability of individual countries to manage their own spectrum. Hence, we assume in the remainder of this discussion that there will be multiple databases (likely one or more per country although the actual number is not important for the discussion that follows).

8.3 With multiple databases a cognitive device would need to know which database to consult in its current location and the protocols to use with that database.

8.4 There are many mechanisms that could be adopted to inform the device as to which database to consult. The information could be pre-programmed in the device, although this reduces future flexibility. Alternatively, there could be a global database list which the device would consult in order to get the address of the relevant local database, perhaps hosted by the device manufacturer. Perhaps most simply, each national database could also store details of other national databases. If a device provided its location when sending a database request a national database could detect that the location was outside of its country and send back details of the appropriate local database to the device. Such an approach would require that devices provided location information and would require some additional protocol standardisation such that a cognitive device could recognise that it had been returned a new database address rather than a list of frequencies in the vicinity.

8.5 Using multiple databases requires harmonisation of protocols such that a device can send the same message to different databases and receive a response that it can understand. As we discussed earlier, we expect industry to deliver such harmonisation and hope that this can be achieved on a global basis.

Harmonisation in Europe

8.6 European alignment can occur through informal, semi-formal or mandatory processes. An informal route would entail all countries individually selecting the same standard. A semi-formal route might be via a recommendation of the European Conference of Postal and Telecommunications Administrations (CEPT) that was widely adopted. A mandatory process might be via European Union (EU) legislation, such as was adopted for ultra wideband.

8.7 A geolocation approach could be enabled via any of these processes. Given the embryonic nature of geolocation and the possibility for significant divergence in the information passed to and from the database, our preference is to seek international agreement on these high level parameters. As a result, we will work within the EU and CEPT to develop appropriate documents.

Harmonisation with the US

8.8 There are no formal mechanisms for ensuring alignment with the US. The Federal Communications Commission (FCC) has developed its own views on an appropriate set of device parameters, as we have been doing in this document. Nevertheless, there are many informal opportunities to work together, sharing evidence and thinking and we will make the most of these opportunities.

8.9 In particular, industry-led groups in the US are now considering geolocation databases and are suggesting architectures and interface standards. We see this as very helpful and plan to work with these groups to provide regulatory input, to promote cross-working with other relevant fora and to align our own work where appropriate.

Section 9

Conclusions and next steps

Conclusions

9.1 This discussion document has considered licence-exempt cognitive access to the interleaved spectrum using geolocation. It has discussed a list of five key issues that we believe need to be addressed and made the following suggestions.

9.2 *The information to be provided by the device to the database(s)*. We suggest that this be flexible with the device allowed to select from providing only its location through to providing location, locational accuracy, device type and preferences as to the amount of information that it receives. As the device provides additional information the database can tailor its response, in some cases allowing higher power levels. We note that this may require standardisation work around the protocols to be used.

9.3 *The information returned from the database(s) to the device*. We suggest that this should be a list of frequencies and power levels for each geographical pixel or location. Alternatively, if the device has moved to a different country, the database might return the address that the device now needs to send its enquiry to.

9.4 *The frequency of update of the database(s) and hence the periodicity with which devices will need to re-consult*. Because some licensed uses of relevant frequencies might require access at short notice – for example some PMSE users - we suggest that devices be required to recheck the database at least every two hours.

9.5 *The modelling algorithms and device parameters to be used to populate the database(s)*. We make some detailed suggestions as to propagation algorithms, assumed device sensitivity and methodology that would enable the database to derive the list of frequencies that could be available for cognitive devices from the information provided about licensed use.

9.6 *The maintenance of the database(s)*. We note that someone will need to develop and host the database and that costs will be incurred. We seek views as to who should be responsible for the database and on what terms, where the costs might fall and what role it would be appropriate for regulators to play.

Next steps

9.7 We are requesting comments on this discussion document by 9 February 2010. We will give due consideration to all responses in determining the most appropriate course of action.

9.8 If we decide to work internationally to achieve harmonisation, it may take some time, perhaps years, for all the necessary processes to be concluded. At present, the key points of interaction are with the FCC and the White Spaces Coalition in the US and within CEPT and the EU in Europe.

9.9 Once we are satisfied that we have taken all relevant factors into account (possibly including further consultation) and done all that we can to ensure appropriate international harmonisation, we will proceed with the necessary steps to licence-exempt cognitive access to interleaved spectrum in the UK. This may involve consultation including draft regulations and then, in the light of responses, making those regulations. Because we do not yet know whether and in what form international harmonisation might be achieved, we cannot give guidance as to how long it might take to reach this stage.

Annex 1

Responding to this discussion document

How to respond

A1.1 We invite written views and comments on the issues raised in this document, to be made by 5 p.m. on 9 February 2010.

A1.2 We strongly prefer to receive responses using the online web form at www.ofcom.org.uk/consult/condocs/cogaccess/howtorespond/form as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see annex 3) to indicate whether or not there are confidentiality issues. This response cover sheet is incorporated into the online web-form questionnaire.

A1.3 For larger responses – particularly those with supporting charts, tables or other data – please email william.webb@ofcom.org.uk, attaching your response in Microsoft Word format, together with a consultation response cover sheet.

A1.4 Responses may alternatively be posted to the address below, marked with the title of the consultation.

Professor William Webb
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. We will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together in annex 3. It would also help if you can explain why you hold your views and how our proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation or need advice on the appropriate form of response, please contact Professor William Webb on 020 7981 3770.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, please specify what part and why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to us to use. Our approach on intellectual property rights is explained further on our website at www.ofcom.org.uk/about/accoun/disclaimer.

Next steps

A1.11 Following the end of the consultation period, we will publish a statement summarising the responses we have received. We will decide what to do next in the light of those responses.

A1.12 Please note that you can register to receive free mail updates alerting you to the publications of relevant Ofcom documents. For more details, please see www.ofcom.org.uk/static/subscribe/select_list.htm.

Our consultation processes

A1.13 We seek to ensure that responding is as easy as possible. For more information, please see our consultation principles in annex 2.

A1.14 If you have any comments or suggestions on how we conducts our consultations, please call our consultation helpdesk on 020 7981 3003 or email us at consult@ofcom.org.uk. We would particularly welcome thoughts on how we could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or our consultation processes more generally, you can alternatively contact Vicki Nash, Director Scotland, who is our consultation champion:

Vicki Nash
Ofcom
Sutherland House
149 St. Vincent Street
Glasgow G2 5NW

Tel: 0141 229 7401
Fax: 0141 229 7433

Email vicki.nash@ofcom.org.uk

Annex 3

Response cover sheet

A2.1 In the interests of transparency and good regulatory practice, we will publish all responses in full on our website: www.ofcom.org.uk.

A2.2 We have produced a cover sheet for responses (see below) and would be very grateful if you could send one with your response. (It is incorporated into the online web form if you respond in this way.) This will speed up our processing of responses and help to maintain confidentiality where appropriate.

A2.3 The quality of discussions can be enhanced by publishing responses before the period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore, we would encourage respondents to complete their cover sheet in a way that allows us to publish their responses upon receipt rather than waiting until the period has ended.

A2.4 We strongly prefer to receive responses via the online web form, which incorporates the cover sheet. If you are responding via email, post or fax, you can download an electronic copy of this cover sheet in Word or RTF format from the consultations section of our website at www.ofcom.org.uk/consult/.

A2.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details or job title to remain confidential, please provide them in your cover sheet only so we do not have to edit your response.

Cover sheet for response to an Ofcom discussion document

BASIC DETAILS

Document title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	☐	Name/contact details/job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation not to be published, can we still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard email text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part) and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name   Signed (if hard copy)

Annex 4

Discussion questions

Q1: Should we suggest only high level parameters, leaving further work to industry, or should we seek to set out full details of parameters to be exchanged?

Q2: Should both closed and open approaches be allowed? Should there be any additional requirements on the providers of closed databases?

Q3: What information should be provided to the database? Are our assumptions about fields and default values appropriate?

Q4: Should the translation from transmitter location to frequency availability be performed in the database or in the device?

Q5: Have we outlined an appropriate information set for the database to provide to the device? Can industry be expected to develop the detailed protocols?

Q6: Is a two-hourly update frequency an appropriate balance between the needs of licence holders and of cognitive device users?

Q7: Is there benefit to devices receiving a time validity along with any database request and to act accordingly?

Q8: What role could push technology play?

Q9: Do you have any comments on the suggested approach to implementing the database for DTT?

Q10: Do you have any comments on the suggested approach to implementing the database for PMSE?

Q11: Do you believe it is practical to implement such a database?

Q12: Is it appropriate for third parties to host the database? If so should there be any constraints? If not, who should host the database instead?

Q13: How can any costs best be met?

Q14: What are the difficulties and expected costs to licence holders in providing the necessary information to the database? Could this information be provided in any other way?