BASIC DETAILS

Document title: **Digital dividend: Geolocation for cognitive access**

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BT Response to the Ofcom discussion document on: Digital Dividend: Geolocation for Cognitive Access

8th February 2010

Summary

BT welcomes this opportunity to respond to the discussion document on geolocation for licence-exempt cognitive access within Ofcom's Digital Dividend Review in the UK. As detailed in our response to the Ofcom consultation on cognitive access in February of 2009, BT's assessment is that the geolocation database approach provides the greatest opportunities for facilitating cognitive access to the interleaved spectrum in the medium term. The benefits of cognitive access for service providers, citizens and consumers are waiting to be realised, and a geolocation solution is a key part of the infrastructure necessary to access this spectrum.

In the responses to the specific questions below we indicate particular network architectures that we could envisage for cognitive radio operation, highlighting that a master-slave topology is likely to be most prevalent, with the master connected to the Internet (and thus to the database) by another access medium other than the interleaved spectrum. In this scenario the slave device will be under the control of the master device and need not contact the database directly. This impacts on the information to be exchanged between the master device and the database, and increases the potential for greater database sophistication, such as the inclusion of time validity information and the use of push technology. We also indicate potential database hierarchies that might be deployed, and discuss database complexity and the possibility for some computation to be performed in the device. We give our views on the frequency at which updates to the database should be made and the periodicity with which devices should reconsult the database to check for such updates.

Answers to the questions in the consultation document

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?

We are in favour of Ofcom suggesting functional and non-functional requirements and high level parameters, leaving standardisation and further work to cross-industry cooperation, including development of architectures, protocols and algorithms. This approach will facilitate novel business models and encourage further innovation. Access to the database should be secure with high availability. A key requirement for efficient cognitive device operation and minimisation of interference to licensed services is that the data is up to date and correct.

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

Experience in related fields shows that openness is nearly always a benefit, and we have a strong preference for the open approach. At the same time we recognise that use of closed databases (probably with proprietary access mechanisms) may be applicable in the short to medium term to provide a faster route to market for some cognitive devices and applications, and we do not feel it is appropriate to mandate a particular approach.

Section 3 of the Ofcom discussion document implies a centralised open database or databases. We envisage that an open database could in practice be distributed, for example in a similar manner to DNS servers (see our answer to Question 4 for more detail on this). Potentially multiple open databases could exist, with database operators offering particular enhancements to the data returned in order to differentiate their service from others, providing choice for cognitive radio service providers and possibly for their end users. The concept of multiple databases brings the potential for interoperability issues, where particular cognitive equipments may be incompatible with certain databases and fail to download the required information, preventing access to the interleaved spectrum. This must be avoided at all costs and standardised protocols must be used.

In all cases, and especially if the closed approach is allowed, it must not be possible for the system to be circumvented or parameters to be manipulated in contravention of the relevant regulations for protection of licensed services.

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

We were unable to locate any discussion in the document with respect to Ofcom assumptions for fields and default values, therefore we are unable to comment on this question as written. At a high level, we agree with the option to send the device model or other identity, but security would need to be in place so that identities cannot be spoofed, for instance to gain a higher transmit power than appropriate for the device type.

For open databases, it is essential that standardised protocols are used to avoid interoperability issues.

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

Very probably the ultimate solution will involve some combination of centralised and local control, but the appropriate mix will vary depending on the application and the CR equipment capabilities. Our expectation is that an initial full UK database containing computed transmitter field strengths to 1 km precision occupies a few tens of megabytes, and thus it is quite feasible for a small device to store a complete copy; however, at 100 metre precision it will be 100 times larger and size may become an issue for some devices. This would be soluble with compression techniques, and the full database may not be required for all devices. However storage size is only part of the problem. The computational complexity for a computation (from first principles, with detailed terrain data and accurate propagation models) of the full database is $O(km/r^2)$, where k is the number of primary transmitters, m is the number of channels, and r is the spatial resolution (1 km or 100 m). This translates to a few hours of number-crunching on a typical Linux desktop PC and is thus only an appropriate task to be carried out centrally. In the short term therefore we believe that an approach where computation of the field strengths is performed centrally to provide a database that can be queried remotely would facilitate faster deployment of cognitive access to the interleaved spectrum, as it reduces the need for implementing new algorithms and protocols in cognitive equipment (base stations and end-user devices).

In the longer term, depending on equipment capabilities, it may be possible for some cognitive equipment (for example base stations) to hold copies of the field strength database and undertake local computation to determine appropriate cognitive channel usage. An architecture could be defined to support the concept of a distributed database, such as a tree structure similar to that used for DNS. Equipment holding copies of the database would need to periodically contact the central database server to see whether updates are available. For updating the local copies, a standard protocol for incremental updating such as *rsync* is probably adequate. Holding a local copy would allow the cognitive device itself to make decisions (for example on channel choice and transmit power, and perhaps other characteristics), which would make the whole approach more distributed, more scalable, and more flexible. The device has greater local knowledge (such as device capabilities); the database would then provide a more global view to help the device determine available frequencies and power levels. We think this approach would also facilitate cognitive devices that may use a range of different modulation and coding schemes or even different access technologies in accessing the interleaved spectrum in an efficient manner. The scheme or technology chosen in real time by a device to access interleaved spectrum would affect the determination of acceptable frequencies and transmit powers by the device. Therefore, it makes sense in the longer term that channel decisions are partly done locally on the device itself, and both central and distributed approaches to database provision should be permitted.

We envisage that initial commercial use cases of cognitive access to interleaved spectrum might include home networks, municipal broadband wireless access, smart metering, and rural broadband. These all involve minimal mobility, and so issues around frequent updating of the device when in motion are not of great significance for these applications. These use cases are also the focus of recent industry standards, including IEEE 802.22 and the ECMA/CogNeA[1] standard.

We believe that the use cases envisaged will almost always be implemented in a master-slave connection topology, with most cognitive functionality (including database access) implemented in the master node (see Fig. 1). Database and protocol design should therefore allow for situations where a master device requests interleaved spectrum frequencies on behalf of end-user devices. In such cases in addition to its own location and device type the master node may have to provide other parameters to the database, for example, a maximum service radius could be specified within which the master may establish links with end-user devices.

[1] http://www.ecma-international.org/publications/standards/Ecma-392.htm

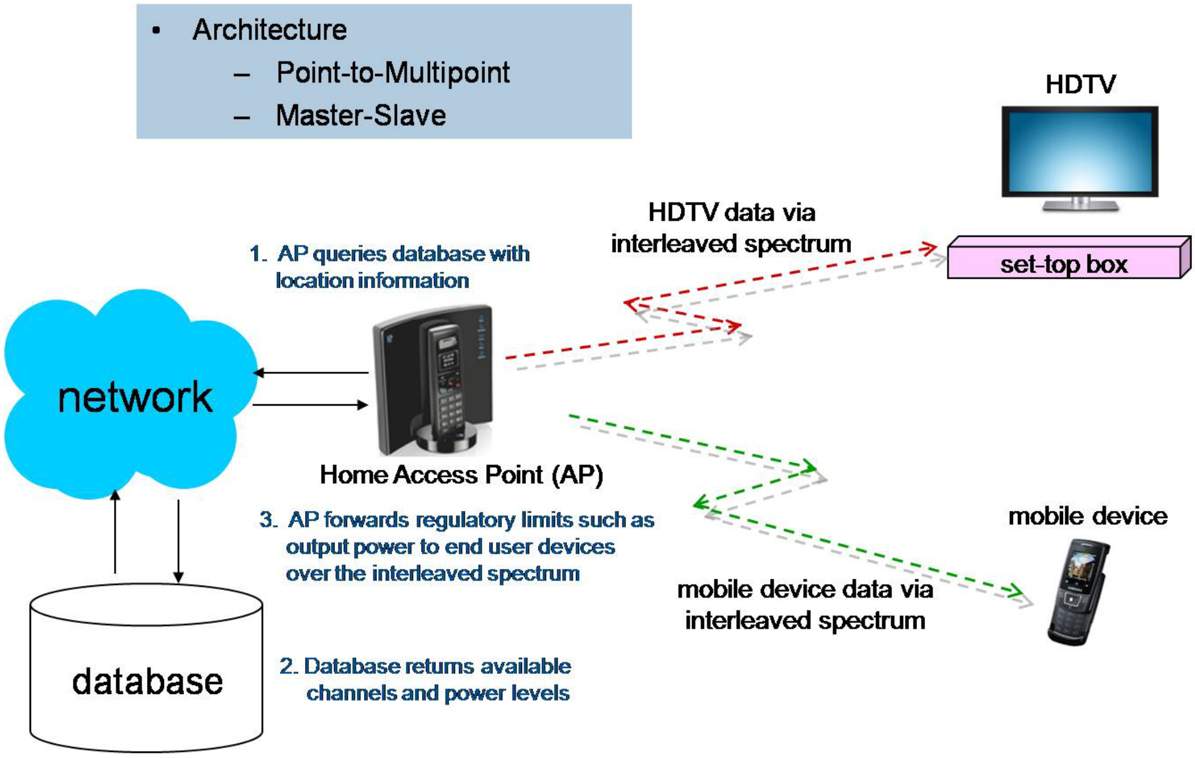

Fig. 1: Hypothetical example geolocation database operation within a master-slave setting where cognitive information is provided to end devices via a master node

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?

We welcome the discussion around the information provided from the database to the device. The exact information set and the detailed protocols should be developed by appropriate standardisation activities through industry consensus.

Provision of start and end frequencies appears to be the most flexible approach to providing frequency information. We agree that a pixel size of 100 m x 100 m is reasonable.

We agree with Ofcom that the capability for querying maximum transmit power is a valuable and important feature in the database approach. In particular we welcome Ofcom's view that this would allow devices to use higher power levels in areas where the frequencies are not in use for some distance (such as rural areas). We prefer this approach to that of the US FCC, which has specified a general 4 W (EIRP) cap on the operation of cognitive devices.

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

The discussion document seems to somehow equate database update frequency with database checking (reconsultation) by devices. This really only applies if there is no 'time validity' information associated with database responses returned to devices, and implies a very basic database implementation. We believe that there is no reason per se for the update frequency of the database to be coupled to the periodicity of devices checking the database. In fact a set update frequency for the database may not be desirable. Database information should always be as up to date as possible, and it does not seem sensible to 'withhold' information that may be available regarding new PMSE assignments and their time validity, simply because a set time period has not elapsed. Also, it should be noted that different devices and/or networks will be checking for database updates at different times since there is no expectation or technical reason for synchronising this activity (and a deliberate lack of synchronisation will smoothen the load on the database). Thus information should be updated as soon as it becomes available, so that new devices/networks start off with the best channel choice and existing active networks migrate to new channels over the course of the reconsultation period.

There should also be some pragmatism in the commencement of actual usage of PMSE channel assignments made by the band manager. We have no experience of the current JFMG band management operations for PMSE, and what we describe may already be a feature of that system. A channel could be marked as 'used for PMSE' in the database in advance of actual need (and additional to the time period charged to the user), in order to allow for cognitive devices to vacate that channel. Thus at any one time the database shows the actual usage plus the expected usage up to the following reconsultation period (e.g. two hours). This would facilitate cognitive radio operation without impacting in any way on PMSE operation.

Similarly, the prompt release of spectrum from PMSE usage should be strongly encouraged and perhaps facilitated through commercial means (such as continuation of charging) in order for channels not to remain sterilised, effectively preventing CR usage due to stale information in the database.

As pointed out in the discussion document, the CR industry has requested 24 hours as an update period/reconsultation period, but the needs of some PMSE usage leads to a shorter period. This is exacerbated by the current lack of UK-wide 'safe harbour' spectrum and by the tuning capabilities of wireless microphones. Ofcom suggests that devices should check the database every two hours in order to accommodate PMSE requirements, and this seems a reasonable figure for a basic database implementation which is unable to provide further information (see answer to Question 7) or operate a push capability (see answer to Question 8). In the future, it may be possible for short notice PMSE usage (such as wireless microphones for 'breaking news' stories) to always use dedicated PMSE frequencies that are not available to cognitive radio, and the periodicity of devices checking for database updates could then be extended. The addition of time validity functionality to the database would also allow reconsultation periodicity to be extended, and the provision of push capability could greatly extend or even eliminate the requirement for reconsultation of the database by the device.

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

A "time validity" parameter would make the database approach somewhat more flexible. The database could employ some intelligence based on previous PMSE usage for that particular location, and could lengthen the time validity accordingly, which would be a trade off against unexpected short term usage for PMSE. In particular, many potential locations for the appearance of PMSE are well-known, and a longer time validity marking could be used in locations where PMSE is very unlikely to appear. In order to facilitate cognitive radio operations we suggest that Ofcom specifies a minimum period (e.g. two hours) between the time that a PMSE device request a channel and the time that the channel is assigned to the PMSE device by the band manager.

A possible obstacle to commercial exploitation of cognitive access to interleaved spectrum is that there is no guarantee that sustained communication services can be provided to users on any given channel due to potentially intermittent availability of these channels. A time validity feature (with intelligent adaptation to take account of location) along with a list of available channels returned by the database would enable cognitive devices/networks to plan ahead for any channel switching decision, such that smooth provision of services to users can be maintained while efficient sharing of spectrum between PMSE and cognitive radio is assured.

Whilst we are in support of the use of a time validity feature, we believe that for most use cases the use of push (or a combination of push and pull) technologies would offer the highest level of flexibility and scalability, as we discuss in our response to Question 8.

Q8: What role could push technology play?

Except for peer-to-peer (adhoc network) applications we believe that in most commercial use cases (which will be master-slave) one can expect that at least the master node is permanently connected to the Internet. In such scenarios the push technology, or publish-subscribe would be a more scalable and reliable alternative to the approach based on regular requests for updates. For example, as soon as a channel is assigned to a PMSE device an alarm can be pushed to all CR devices within the relevant geographical location therefore guaranteeing that CR devices will start to vacate the channel. A device could previously have indicated to the database server which parts of the database need updating, minimising the amount of pushed data and the number of devices to which it must be addressed. For instance, once the device has reported its location then probably only data for the appropriate pixel and its neighbouring pixels needs to be downloaded.

The implementation of a push architecture should include some sort of secure identity exchange and acknowledgement of safe delivery, so that negative acknowledgements or lost data can be followed up by resending the data.

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

BT has no comment on this question.

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

BT has no comment on this question.

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

Yes, based on the ongoing work in the US and also our own recent research work to investigate the database approach, we believe that implementing such a database is computationally feasible and practical. We note that companies have already started the application process with the FCC to be the US database operator.

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?

Allowing third parties to host the database may provide commercial opportunities and should be permitted. Requirements for companies proposing to host the database should be well defined and delivery of the necessary security, availability and accuracy should be verified.

Q13: How can any costs best be met?

Licensed and licence exempt users will both benefit from the database. Ofcom has consulted separately on arrangements for a band manager with obligations towards PMSE, and the new database for cognitive usage will continue to protect licensed usage, including PMSE. In practice there may be some linkage or commonality between the band manager function (perhaps itself implemented through a database) and the new geolocation database for cognitive devices. We recognise the difficulty of collecting revenue from end users of cognitive radio, their service providers and the device manufacturers to cover the costs incurred by database providers for provision of information to cognitive devices. We believe that it will be possible to agree commercial arrangements over time to cover this aspect of database operational costs.

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?

BT has no comment on this question.

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