Activity in the WiFi bands - An Objective Approach to Estimation

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Abstract

A survey of IEEE 802.11 WiFi usage in the 2.4 GHz and 5 GHz bands has been carried out by Ofcom with a view to gaining a clearer understanding of the state of these Licence-Exempt spectrum bands. The very large amount of data gathered was analysed by MASS Consultants who had the challenge of deriving meaningful results and insights. The study concluded that the majority of this network degradation is probably attributable to the interference between WiFi networks in an unmanaged environment rather than interference from other technologies such as Bluetooth, analogue video senders and microwave ovens.

Background

Users of licence exempt (LE) bands are not formally protected from interference, as in licensed bands, but the economic benefit of having efficient spectrum utilisation is apparent. Equipment for use in the UK must adhere to the appropriate Ofcom Interface Requirement document [1], which provides the minimum requirements only. The specific services are not detailed so allowing a wide range of possibilities from movement detection radar to data transmission.

Measurements to assess the usage of the LE bands have been undertaken by Ofcom (and the Radiocommunications Agency) for at least twenty years. Study AY4434 of 2003 [2] compares 2.4GHz data gathered in Glasgow during 2003 to data gathered in 1994. A study in 2009 [3] attempted to draw maps of key urban centres showing WiFi usage and congestion. In addition generalised noise measurement across 100 MHz and 10.6 GHz [4] has provided a contribution to understanding activity in licence-free bands. The amount of research effort is an indication of the importance Ofcom as spectrum regulator places on having accurate and objective spectrum usage information.

The Requirement

In early 2012 Ofcom requested proposals to address the following questions:

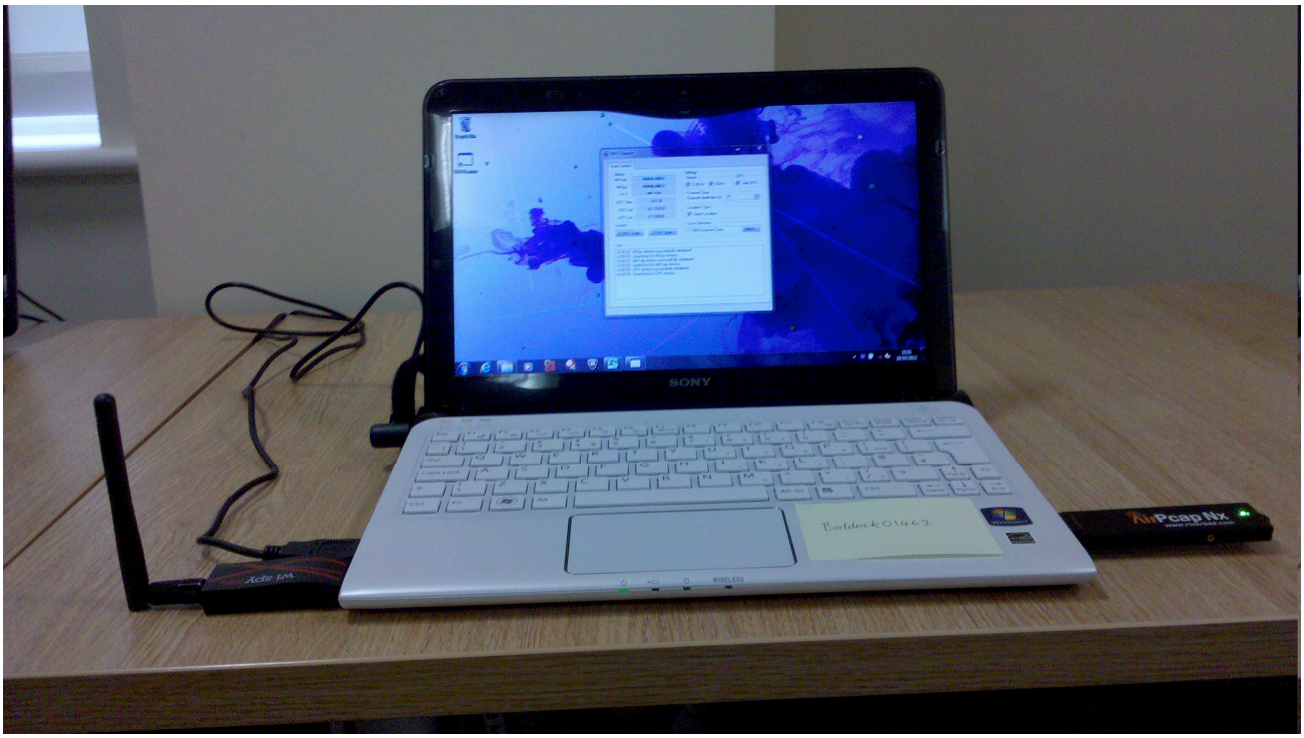
- Are the LE bands delivering a suitable environment for innovation and e-commerce in the UK?
- Is it possible to devise a robust, repeatable approach to measuring utilisation of the 2.4GHz and 5GHz LE bands and link this to the quality of service experienced by users?
- Are Wi-Fi devices currently experiencing a degradation of service, e.g. congestion, interference, incorrect configuration of devices?
- Where and when is degradation occurring?
- What steps could be taken to mitigate these problems?

It was understood that WiFi is most important service in the 2.4GHz and 5GHz bands but that other (non WiFi) services exist and their presence would need to be considered.

“Utilisation of key licence exempt bands and the effects on WLAN performance Final Report Issue 1 June 2013” [5] was produced to address these questions.

Methodology

Sensors to monitor both the WiFi traffic and provide a spectrum analysis function are available in the form of USB dongles. The relatively low cost of this approach compared to a more conventional spectrum monitor and logging approach allowed three sets of equipment to be deployed simultaneously. The image below pictures the implemented system.



Bespoke software prepared by MASS saves a summary of the data at regular intervals for later post processing. Both spectrum and WiFi monitoring equipment operate in a sampling fashion monitoring a specific frequency for a short interval and then moving on to the next frequency. This sampling process means that a statistical approach was necessary in contrast to a method where all data is gathered verbatim. As a consequence data was aggregated over a defined period which was initially set to one hour in line with established noise measurement methods.

Care was taken in the preparation of the logging software to record only data from the radio header of the WiFi frame. This was considered important to avoid any risk of intercepting and storing user data.

Trials were carried out under laboratory conditions to verify the accuracy of the data gathered against known data traffic conditions such as video steaming.

Measurement Campaign

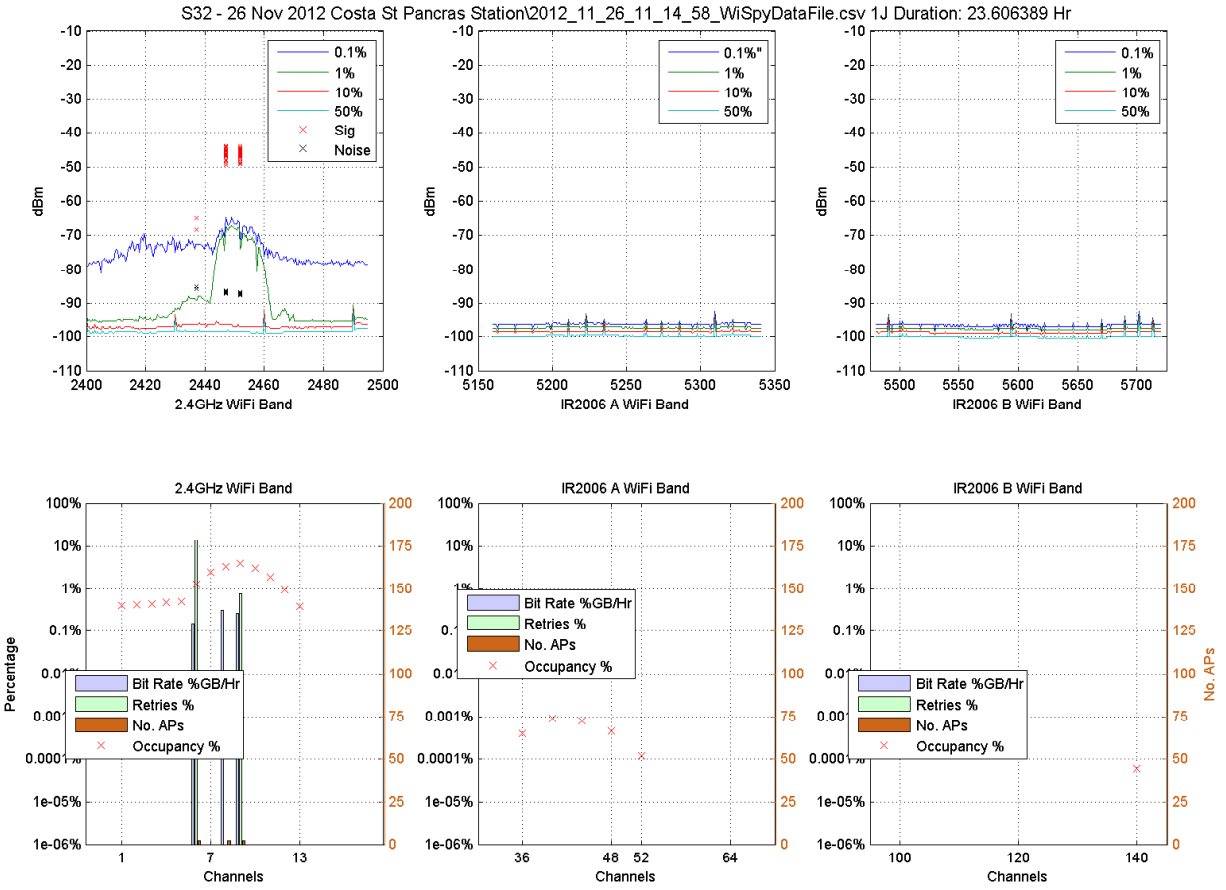
Ofcom's Baldock staff carried out around 30 measurements during the latter part of 2012. Each measurement gathered data continuously for up to a week. Sites were classified into houses, apartments, cafes and shopping centres and were urban in nature. Ofcom web pages [6] gives many details of the sites etc.

It was intended that the measurement laptop be placed in the environment to be monitored in exactly the same manner as user equipment would be deployed. In practice it was necessary to make the installation secure which often meant placing the laptop in a locked cupboard or similar place. A correction factor was included at post processing to account for the slightly reduced RF levels to be expected in that location.

Post Processing - Visualisation

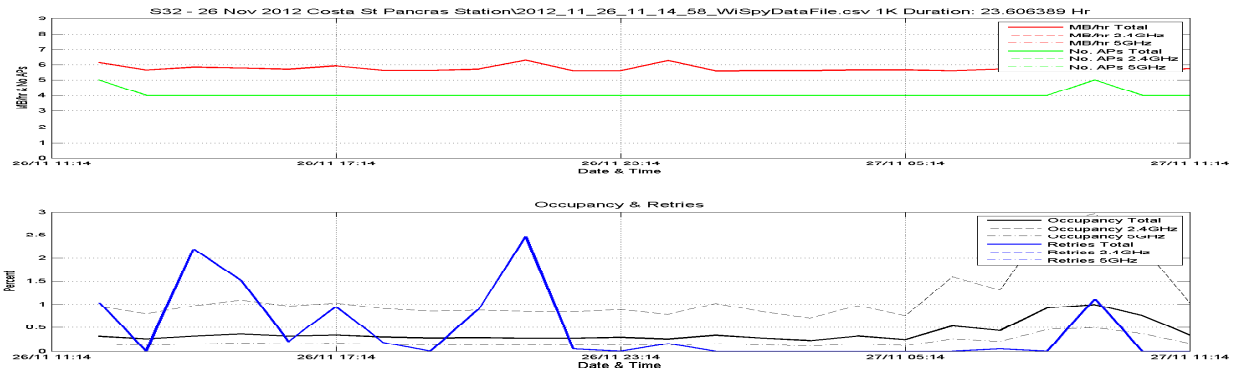
The measurement campaign resulted in approximately 1.2GB of data even when aggregated over one hour intervals during recording. This quantity of data had to be summarised in some way to permit comprehension but, in performing this data reduction, care was needed to avoid discarding important details.

The first step was to plot the data from each specific site over the whole time. The following example plot aggregates data over 23 hours and allows a form of visualisation with frequency/channel in the x axis.

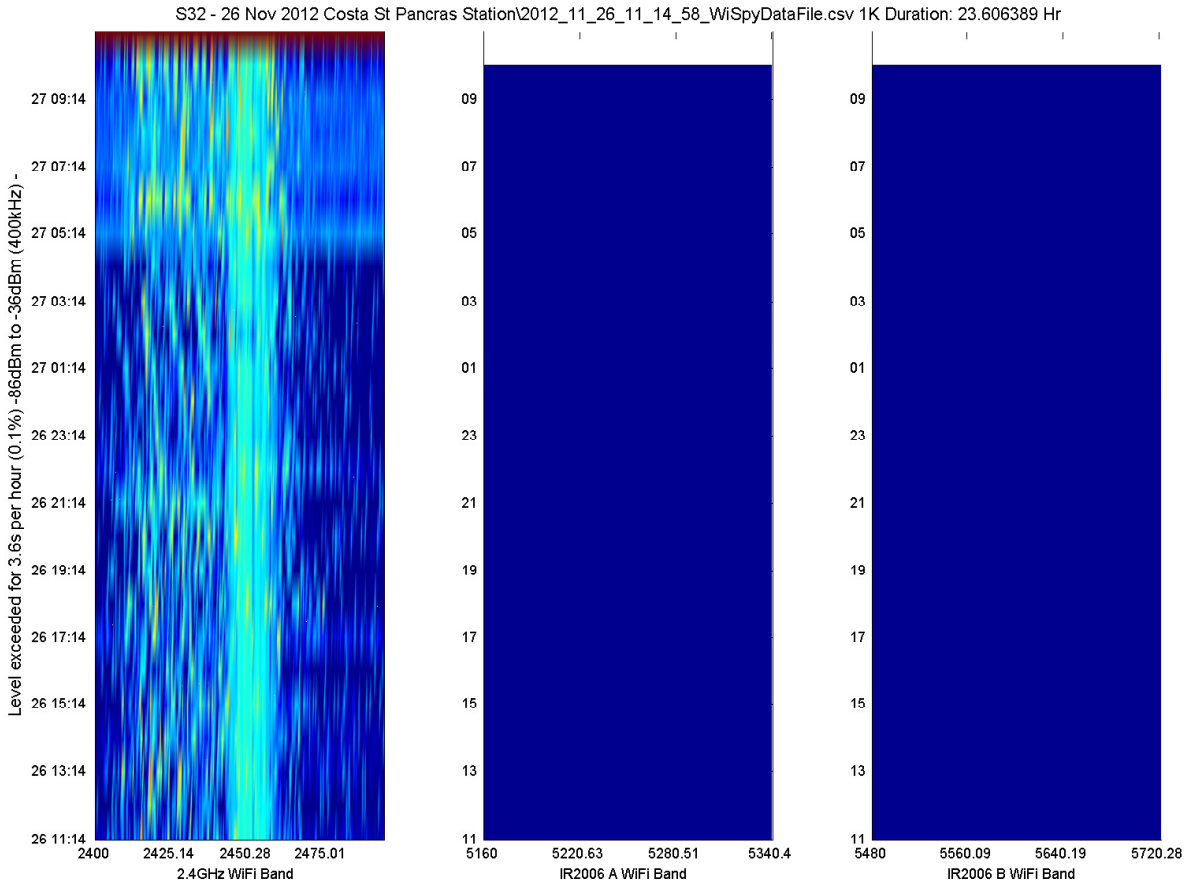


Spectrum analyser data for the three WiFi bands was plotted at the top while the corresponding statistics from WiFi radio header was plotted below. In addition WiFi signal levels were superimposed on the spectrum analyser plots and occupancy (derived from spectrum analyser data) was superimposed over the WiFi metrics.

Data from all WiFi channels was aggregated and then plotted over time.



Spectrum analyser data was plotted as a spectrogram. Note that in this plot time is the y axis and frequency/channel is the x axis.



Analysis

Data from the busiest hour was used to derive metrics the following metrics.

Metric – Spectrum analyser	**Comment**	**Classification**
RF level exceeded for a specific proportion of time	Plotted above	
Proportion of time an RF level is exceeded	'Occupancy'	Primary
Metric – WiFi radio header	**Comment**	
Number of Access Points	Indicates quantity of infrastructure	Secondary
Number of devices	Indicates quantity of users	
Mean data rate per channel (throughput)	Very user dependent	Secondary
Mean data rate per device	Very user dependent	
Number of frames	Independent of coding scheme	
Proportion of data, management and control frames	Hard to interpret	
Proportion of CTS, RTS and ACK frames	Indicates 'MAC stress'	
Retry rates	Indicates 'MAC stress'	Primary

It was clear that to facilitate an understanding of usage of these bands, the one or two most important parameters should be identified. It was found that occupancy and frame rate have a correlation when services other than WiFi were absent. This logic allows occupancy to be classified as a primary metric that is sensitive to all types of service. Note that this occupancy/ frame rate metric does not relate directly to data throughput as the modulation schemes within WiFi vary greatly.

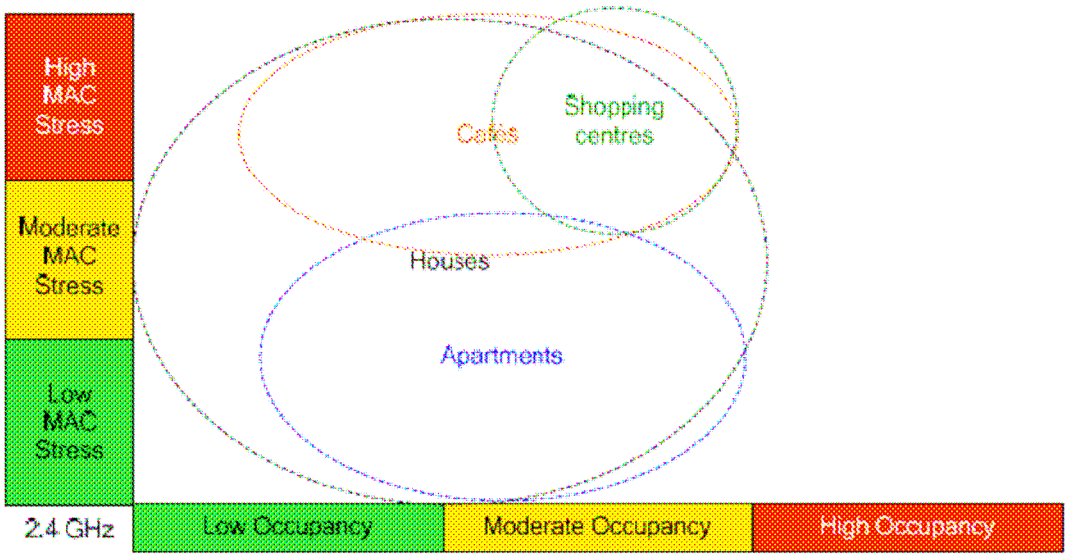
Media Access Control stress (MAC Stress) was also selected as a primary metric. This parameter is derived from the WiFi radio header and indicates the proportion of re-tries and so disturbance present.

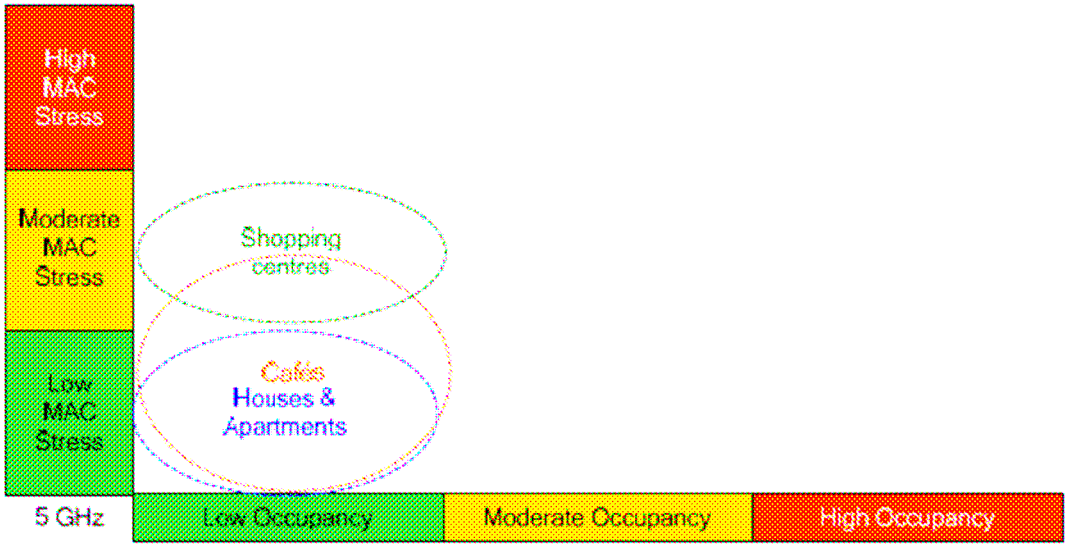
Number off access points was considered to be secondary metric as this indicates the amount of infrastructure installed or network density but not data traffic.

Throughput in GB per hour was also classed as a secondary parameter as this can vary greatly dependent on the modulation scheme in use.

Overall Conclusions

Having identified the two primary metrics, a plot of the following type was generated. This summarises the whole campaign and indicates that spare capacity remains to be exploited. It also indicates that the WiFi MAC protocol is working to resolve lost frames in city centre situations. Some indications of services other than WiFi were detected but these were not significant. It can be concluded that the raised MAC stress is attributable to mutual interference between unmanaged WiFi networks in the 2.4GHz band.





Fine time resolution exercise

During the project it became clear the aggregating over a one hour period might be obscuring transient events occurring on a shorter timescale. It was argued that a loss of data throughput for even a few seconds would seriously affect video streaming. To investigate this issue, further measurement were carried out at selected locations and the data plotted. See page 51 of the report [5], which describes this fine time resolution exercise. The overall effect was not felt to greatly alter the conclusions drawn above.

Discussion in relation to the questions given in the requirement

The LE bands can be seen to be delivering a suitable environment for innovation and e-commence in the UK. It is clear that however that the 2.4GHz band does suffer some congestion although this would be manifest as reduced throughput rates rather than complete failure. The 5GHz bands are relatively unused.

A robust method of measuring utilisation of the WiFi bands has been demonstrated. It is a fairly low cost method that could be applied in future. However, it was found that the quality of service that the user of the WiFi device experiences cannot be assessed using the information gathered. User experience is dependent on many factors that are external to the WiFi network and, in addition, the data transmission needs of user applications is also likely vary greatly.

WiFi devices may be experiencing some degradation of service but this is likely to be limited to short periods. Locations where this is a likelihood are shopping centres and cafes in city centres. Migrating to the 5GHz would very largely resolve this issue.

Ofcom Consultation

“Utilisation of key licence exempt bands and the effects on WLAN performance Final Report Issue 1 June 2013” [5] became an input document to an Ofcom consultation in 2013. Ofcom document “The future role of spectrum sharing for mobile and wireless data services. Licensed sharing, Wi-Fi, and dynamic spectrum access” [7] provides full details.

Acknowledgements

Gary Clemo at Ofcom (Riverside House) commissioned the work described and we are grateful for his permission to present it here. In addition staff at Ofcom (Baldock) carried out the necessary field measurements.

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Paul Hansell of Aegis Systems contributed to the report.

The views expressed are those of the author and not necessarily those of Ofcom or MASS.

References

[1] Ofcom Interface requirements.

http://stakeholders.ofcom.org.uk/spectrum/technical/interface-requirements

[2] AY4434 September 2003 MASS Document MC/SC0390/REP010/1

http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/other/2-4ghzbandmonitoring.pdf

[3] MASS Document Estimating the Utilisation of Key Licence-Exempt Spectrum Bands MC/SC0710/REP003/3

http://stakeholders.ofcom.org.uk/binaries/research/technology-research/wfiutilisation.pdf

[4] MASS Document: Autonomous Interference Monitoring System Final Report MC/SC0585/RFP016/1

http://stakeholders.ofcom.org.uk/binaries/research/technology-research/aims2_1.pdf

[5] MASS Document MC/SC0973/REP005/1

Utilisation of key licence exempt bands and the effects on WLAN performance
Final Report Issue 1 June 2013

http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2013/report.pdf

[6] Ofcom web page: Utilisation of key licence exempt bands and the effects on WLAN performance

http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/key-licence-exempt-bands/

[7] Ofcom Document:

The future role of spectrum sharing for mobile and wireless data services. Licensed sharing, Wi-Fi, and dynamic spectrum access

http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf