Annex 3.3: Willingness to pay and future spectrum release

In this annex we respond to the two themes of Ofcom's annex 9 of the August consultation, "*technical and commercial evidence*", namely:

- *"The possibility of greater certainty around spectrum availability, and*
- *Network cost modelling*"[1]

The two points are interlinked. We show in this document that since the Auction (and furthermore since our previous response) the extent of the certainty of future spectrum availability has increased significantly, and is much stronger an effect than merely the possibility expressed by Ofcom. Such certainty takes two forms:

- A certainty that 2.4 GHz, 3.4 GHz, 1452 - 1492 MHz and 700 MHz spectrum will be released for mobile broadband use within a reasonable timeframe, and
- A certainty that it is Ofcom's intention to release substantial additional spectrum for mobile use, as and when it is needed to satisfy mobile data demands, in order to maximise the consumer benefit from mobile data services.

Each of these will inevitably have had a downward influence on the forward looking value of 900 MHz and 1800 MHz spectrum. This is addressed in section 1 of this annex.

Furthermore, we examine in section 2 the validity of Ofcom's criticism of the use of network cost modelling to provide useful information on spectrum value. Ofcom's major criticisms are that the range of potential values output by a cost model would be too broad to be useful, given the large variation of input assumptions that is possible, and that the 700 MHz model does not appear to be suitable to the purpose of valuing 900 MHz spectrum. At present the illustrative 700 MHz model is producing a range of values between £0m and £138m per MHz.

However there is one very useful observation that we can make from the way Ofcom has used the 700 MHz model to illustrate the value of 900 MHz spectrum. This is that the use in the network by a mobile operator of 2 * 5 MHz of 900 MHz spectrum is very considerably lower than the use of 2 * 5 MHz of 800 MHz spectrum in that model over the 20 year period from today. Although from a theoretical desk-top point of view, in the long run, a unit of 800 MHz spectrum may potentially become equal in utility to an equivalent volume of 900 MHz, it can be seen from the cost model that the present use and hence the forward looking value to an operator of the LTE use that can be obtained from the auctioned 800 MHz spectrum must be very considerably more than that which can be obtained from 900 MHz spectrum. Cost modelling thus can support the international benchmarking analysis, and thus Ofcom's conclusion from that

[1] Further consultation at A9.2

analysis that the value of 900 MHz is at a considerable discount to that of 800 MHz. We would suggest however that any detailed corroboration of this relative value from cost modelling would suggest that the present discount in value between 900 MHz and 800 MHz is likely to be greater than the 62% relative value extracted from Vodafone's analysis of the international benchmarking evidence. This topic was considered in some detail in Annex 8 of our previous response – we briefly summarise the relevant arguments in section 2 below.

Despite this general point, we can agree with Ofcom's conclusion that the 700 MHz model is not particularly fit for the purpose of 900 MHz spectrum absolute valuation, since it was built for a rather different purpose of identifying the consumer benefits of the use of 700 MHz spectrum for mobile use. But this does not axiomatically lead to the presumption that the general cost modelling approach is invariably unhelpful.

Furthermore we can question the validity of some of the assumptions that have been applied in the 700 MHz model to produce a valuation for 900 MHz spectrum – it would appear that it is likely that some of the assumptions adopted are producing an erroneously high set of values for 900 MHz spectrum and that if this were to be addressed in a purpose built model, the range of values for 900 MHz currently produced by the model would significantly contract downwards.

But beyond this necessary downwards adjustment, we consider that even in the current absence of a formal purpose built cost model for 900 MHz, the application of the concepts underlying a cost modelling approach can contribute two useful insights towards spectrum valuation, both of which lead to the conclusion that a lower set of spectrum values is appropriate for 900 MHz spectrum fee setting than the broader range of values generally indicated by a simple cost modelling exercise.

Firstly we show that the implication of Ofcom's current expressed policy with regard to mobile spectrum, in terms of the declared intention to release additional spectrum beyond its current priorities of 700 MHz, 2.3 GHz and 3.4 GHz, if required by future data traffic growth, has the effect of "capping" the general forward looking spectrum value that can be produced by cost modelling, by eliminating any "high traffic volume with low additional spectrum" scenarios from the reasonable range of spectrum values. It is this particular pairing of assumptions that must (other things being equal) supply the highest spectrum values of any cost modelling output. It follows therefore that the range of spectrum values shown by any cost modelling must not be as wide as Ofcom suggests and would be on average very much towards the lower end of the range output by the illustrative 700 MHz model (even before any other necessary adjustments were to be applied to the model).

Secondly, we also consider in section 2 the point that high volume data forecasts (or more strictly data forecasts in general) cannot in any event be adopted in any spectrum valuation cost modelling scenario without consideration of the willingness to pay by consumers for any increase in the volume in mobile services. There needs to be a match between the cost of supply and the available revenue from a given level of demand. Ofcom's tentative exploration of cost modelling through the use of the 700 MHz model merely develops a "value" of spectrum derived from the difference in the

level of network investment required to provide an assumed demand of traffic capacity with and without additional spectrum – it is in effect identifying a point of indifference for operators, given that by model definition, the level of total network costs remains the same with and without the additional spectrum that could be used for LTE data services. Such an analysis says nothing as to whether such investment will be justifiable by operators – i.e. whether the incremental revenue that may result from such capacity investment will be sufficient to allow the investment to be profitably made, and therefore whether it is possible to satisfy demand at this level of network investment (which by model methodology is the same with or without the additional spectrum).

A purpose written cost model would in addition need to compare the cost of provision of incremental capacity (by network investment with or without incremental spectrum) with the willingness to pay for incremental capacity. In circumstances of infinite consumer willingness to pay for mobile services at any price there would most likely be little issue with a cost of spectrum suggested by 700MHz model style cost modelling, as it might be expected that the investment in additional spectrum at any value would always lead to additional profitable supply of data capacity, to the benefit of both the mobile operators and to the UK in general.

But both the uncertainty of the willingness to pay by consumers for incremental data, and the overall perception that consumer benefits will be maximised by the highest possible supply of mobile data point in the same downwards direction of valuation. This is that the most efficient use of mobile spectrum is to permit the maximum possible supply of data traffic (and thus aid in the stimulation of demand), by avoiding the alternative of substantial cost to mobile operators of incremental new site investment. In these circumstances if mobile operators have to pay a high valuation of spectrum that is simply equivalent to the potential saving in network investment, then no additional capacity investment results from the provision of that spectrum at that cost. But if operators have to pay less than this, then more capacity expansion becomes possible for a given network investment. Therefore a spectrum valuation that maximises UK benefit will be one at the lower end of any cost modelling outputs indicated by the 700 MHz model (or any purpose written alternative).

Both these factors tend to eliminate the possibility of the validity of any of the higher levels of spectrum values that could be produced by cost modelling of the 700 MHz model type (even when such a model is suitably purpose built for the specifics of 900 MHz for LTE use) and also point toward the suggestion that a conservative valuation of spectrum is the one that will most likely allow the consumer benefits of mobile broadband to be best satisfied, i.e. by maximising the provision of capacity within the limits of what is affordable to operators given the limitations of customer willingness to pay for additional traffic. We would expect that an impact analysis of the costs and benefits of alternative levels of spectrum fees, the need for which is discussed in annex 3.1 of our response, would have drawn a similar conclusion.

Therefore, Ofcom in taking its view of the value of non-auctioned 900 MHz and 1800 MHz spectrum should take account of these four factors:

- the very much reduced range of outputs that would result from resolving the admitted unsuitability of the 700 MHz model by substituting a purpose built cost model for 900 MHz, with appropriate parameters and assumptions,
- the lower valuation of 900 MHz than 800 MHz implied by the cost model's intensity of use of the two bands,
- the downward pressure on spectrum fee levels arising from the increased confidence in the availability of future spectrum both of Ofcom's immediate priorities of 2.3 GHz, 3.4GHz and 700 MHz and beyond that, the prospect of additional spectrum as traffic demands require, and
- the limitations imposed by the lack of consumer willingness to pay for additional data traffic set against the consumer benefit of maximising the level of such traffic.

All of these point to the same conclusion – that a lower spectrum value is appropriate in the context of fee setting than the £23m and £14m per MHz for 900 MHz and 1800 MHz respectively that is provisionally adopted in the current Ofcom consultation.

Section 1 Future spectrum release

Ofcom recognises the risk that (now somewhat aged) evidence from previous auctions - including the UK auction itself - may overstate the value of spectrum given the continuing increase in certainty over release in the UK of additional mobile broadband spectrum. Ofcom states:

> *"We recognise the possibility that market values may have changed since the time of the UK 4G auction early in 2013. It is possible that there have been changes which could have increased the value of spectrum in the ALF bands,"*

However Vodafone notes that in reality Ofcom does not advance any reasons why this upward movement might have occurred. Ofcom continues:

> *"But there are also developments which may have reduced their value."*[2]

Here Ofcom does provide some evidence:

> *"To take account of the **possibility of greater certainty of availability** since the 4G auction of spectrum bands that may be substitutes for the ALF bands, we propose to set ALFs conservatively."*[3]

Ofcom in fact is somewhat understating the strength of this factor. Closer analysis of Ofcom's spectrum policy position demonstrates that it has committed itself not only to the release of considerable quantities of additional "mobile broadband" spectrum in the short to medium term (2.3 GHz, 3.4 GHz, 1452-1492 MHz and 700 MHz) but also to release further spectrum as and when it is required for mobile services.

The effect of this statement of policy must have the impact of reducing forward-looking spectrum values (compared to the time before this statement was made).

The developments that have reduced spectrum value are relatively straightforward. They relate to increased certainty of the supply of alternative mobile spectrum. Ofcom, in its modelling work described in annex 9 of the present consultation, considers the value to the operator of an additional 2 * 5MHz of 700MHz (as a proxy for 900MHZ) for LTE use. The present core bands for LTE are those that are in current use for LTE, i.e. 800MHz, 1800MHz and 2600MHz.

The modelling by Ofcom assumes that the future long term value of 900 MHz spectrum lies in its ability to supplement the existing LTE spectrum. We would agree. But in this its utility is compromised by the fact that 900 MHz is not currently an effective LTE band – as was discussed in annex 8 of Vodafone's January submission. This limitation does not appear to have been fully recognized in Ofcom's modelling of spectrum value, as we discuss below.

[2] Consultation at 1.39
[3] Consultation at 1.41, Vodafone emphasis

The existence of alternative substitute bands will also drive down the value of the band – the more clear the availability of substitute bands becomes, the lower the value of 900 MHz becomes. Vodafone made this overall point in its response to the October 2013 ALF consultation and Ofcom has accepted it:

> *"Possibility of greater certainty of availability of future mobile spectrum*
>
> > *1.40 The bands where there is currently most momentum behind mobile use are 700 MHz, 2.3 GHz, 3.4 GHz and 1452 - 1492 MHz. These bands were all recognised at the time of the 4G auction as likely to become available for mobile use. However, developments since the 4G auction have progressed the position in relation to each band and this might have further increased the degree of confidence in their future availability. The evidence suggesting the possibility that there could be greater certainty of availability in one or more of these bands as a result of these developments is set out in Annex 9. This might reduce the forward-looking market value of the ALF bands, 900 MHz or 1800 MHz (or 800 MHz or 2.6 GHz which we use in step 1 of our approach). This is because the bands set out above may be substitutes for the ALF bands (even if not necessarily close substitutes).*
> >
> > *1.41 To take account of the possibility of greater certainty of availability since the 4G auction of spectrum bands that may be substitutes for the ALF bands, we propose to set ALFs conservatively."*

The somewhat enlarged discussion in annex 9 of the present consultation on the matter is pretty limited in tone – it does not draw out the substantial progress that has been and is being made by Ofcom in increasing the certainty of the availability of these bands.

> *"A9.6 The bands where there is currently most momentum behind mobile use are 700 MHz, 2.3 GHz, 3.4 GHz and 1452 - 1492 MHz. For all of these bands, the suggestion that they could be used for mobile broadband pre-dates bidding in the UK 4G auction in January and February 2013. However, we accept that there have been further developments since then."*

Ofcom then briefly summarises in A9.6 and A9.7 the work that it has done on these bands, and also the potential release of additional spectrum beyond these. Ofcom then adds a rider:

> *"A9.9 In any case, most further spectrum releases will take place some years into the future. We discuss the development of the ecosystem for LTE900 (which has implications for the timing of LTE use by 900 MHz compared to other bands) in paragraphs A7.80-A7.82 of Annex 7."*

We would obviously agree that all of the specific bands identified above have been suggested for mobile use for some time. Furthermore in the MTR model Ofcom in its current provisional form[4] calculates that there is at present sufficient spectrum available for the average operator for LTE use, to absorb the anticipated increase in data traffic

[4] In the model supporting the June 2014 MTR consultation

in the short term, without needing to draw on either LTE 900 or any additional band. However this will not last indefinitely.

The fact that this additional spectrum has been on a shopping list for some time is no guarantee of its delivery into the hands of the mobile operators – it is the level of certainty that has changed from the date of the auction. As we have discussed before it would not have been appropriate for Auction bidders to have discounted their immediate need for usable LTE spectrum on the grounds that some other possibly usable spectrum might become available at some relatively ill-defined future date. Such spectrum would have been a totally inadequate substitute for the auctioned spectrum.

But once the operators had secured from the Auction[5] sufficient spectrum to be able to launch competitive 4G services, the need for any additional spectrum is only to provide additional capacity when required. Given the uncertainty of data demand forecasts, it is not clear when this additional capacity will be required. As a result of the carrier aggregation capability of LTE-A and the steady increase in additional harmonised bands it is of less criticality than in the past which particular spectrum band will be needed or will be used to provide any additional capacity. Therefore any increase in the certainty of supply of future additional spectrum will inevitably have a downward impact on the value of the non-core LTE spectrum, such as 900 MHz.

There are two relevant points arising from Ofcom's post-auction work:

- The ongoing international developments plus the actions of Ofcom have substantially increased the likelihood (and improved the certainty of the timing) of the 2.3GHz, 3.4 GHz and 700 MHz spectrum being made available for mobile use than operators could have expected at the time of the auction.

- But furthermore there has now been in the Mobile Data Strategy statement a clear exposition of Ofcom's policy that if needed, additional spectrum will also be made available.

Ofcom's conclusion in 1.40 quoted above is pretty clear - that there is very considerably greater certainty than at the time of the auction in February 2013 that both more spectrum will be made available and that spectrum release is proceeding on a known timetable. It is now very certain that the 700MHz, 2.3GHz and 3.4GHz bands will be made available for mobile use within the next few years: but significantly in addition the mobile data strategy statement makes clear that if needed additional spectrum will be made available for mobile use over a longer time period.

2013 spectrum activity post Auction

Vodafone laid out in its response to the October 2013 consultation in January 2014 the ways in which the confidence in the availability of additional spectrum had increased

[5] And by the release of 2*15 MHz of 1800 MHz by EE to H3G

between the time of the auction and January 2014. We do not reiterate these 2013 activities here, but simply list the relevant Ofcom publications.

- Spectrum pricing for terrestrial broadcasting March 2013
- Future demand for mobile broadband spectrum and consideration of potential candidate bands March 2013
- Annual plan 2013/14 March 2013
- Future use of the 700 MHz band April 2013
- Public Sector spectrum release June 2013
- UHF and VHF spectrum planning – call for inputs to Ofcom's plans for the potential procurement of models, tools & services July 2013
- Spectrum management strategy - Ofcom's approach to and priorities for spectrum management over the next ten years, October 2013
- 2.3 and 3.4 GHz spectrum award: consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a call for inputs on other aspects of the award, October 2013
- Mobile data strategy consultation November 2013
- Draft annual plan 2014/15 December 2013

2014 spectrum activity post submission of Vodafone previous consultation response

It is very obvious that there have been further developments since our response to the previous spectrum consultation was submitted, that further increase the confidence in the availability of substitutes, in the near term and further in the future.

It is worth highlighting these, as they will only have served to further reduce the value of 900MHz spectrum. Simply from inspecting Ofcom's website we can see the following substantial developments since the Vodafone consultation response was submitted in January 2014:

Ofcom publications:

- Public Sector Spectrum Release (PSSR): Technical coexistence issues for the 2.3 and 3.4 GHz award February 2014

  http://stakeholders.ofcom.org.uk/consultations/pssr-2014/

- Ofcom Annual Plan, March 2014.

  http://www.ofcom.org.uk/about/annual-reports-and-plans/annual-plans/annual-plan-2014-15/

- Ofcom spectrum management strategy Statement, April 2014

  http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/

- Mobile Data Strategy Statement, May 2014

  http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/statement/

- Consultation on future use of the 700 MHz band - Cost-benefit analysis of changing its use to mobile services, May 2014

  http://stakeholders.ofcom.org.uk/consultations/700MHz/

- Variation of UK Broadband's 3.4 GHz Licence, June 2014

  http://stakeholders.ofcom.org.uk/consultations/uk-broadband-licence/

- Ofcom consultation on the UK preparations for the World Radiocommunication Conference 2015 (WRC-15), June 2014

  http://stakeholders.ofcom.org.uk/consultations/wrc15/

We consider each of these in more detail below, but fundamentally the documents are cumulative in impact in indicating the continuing progress towards the release to mobile of Ofcom's current priority spectrum of 2.3 MHz, 3.4 MHz and 700 MHz. They build on, and reinforce each other in this respect. The 700 MHz consultation is an unequivocal endorsement of the policy advantage of the use of this band by mobile over DTT, and sets out potential release timings for the band. The spectrum management Statement and the MDS Statement significantly build on this, by looking beyond these spectrum releases to consider what else is possible and might be needed in response to the expectation of mobile data traffic growth. The WRC-15 input document summarises Ofcom's view of the priority of these additional bands.

The Spectrum Management Statement also points to the wider social benefits of mobile data consumption, that is greater than any simple producer surplus - the 700 MHz consultation addresses a similar point, in that Ofcom uses the possible cost saving from mobile network operator use of the spectrum as a proxy for the consumer benefits, but then estimates a further set of consumer benefits on top of this. The implication of this work is that consumer benefits will be maximised by the greatest possible supply of capacity to meet the traffic demand.

The conclusion that can be drawn from this evidence is that there is an increasing certainty of additional spectrum on top of that established by Vodafone in our January 2014 response to the previous consultation, and this increasing certainty acts to reduce the value of incremental mobile broadband spectrum such as 900 MHz.

But in addition there has been the publication by the DCMS of the government's UK spectrum strategy, March 2014 – *"delivering the best value from spectrum for the UK"*

We consider this report first, before quoting key passages from the various Ofcom statements, consultations and other documents that have been published since January 2014. We quote from the Ofcom documents extensively without apology, as we consider that Ofcom makes Vodafone's case on the increasing certainty of future spectrum supply very coherently.

1.1 DCMS UK spectrum strategy

https://www.gov.uk/government/publications/spectrum-strategy

Effectively this lays out the overall structure which the individual Ofcom documents can be seen to be following and elaborating. It is a high level document, concerned with maximising the consumer benefit from spectrum; the most relevant quote can be taken directly from the ministerial foreword:

> *"We want to make the most of any globally agreed changes in spectrum use, such as those which will support ubiquitous mobile broadband. And we want to be a global leader in driving better value from spectrum."*
>
> *"Our vision is for use of spectrum to double its annual contribution to the economy by 2025 through offering business the access it needs to innovate and grow, and everyone in the UK the services they need to live their lives to the full."*

It follows quite straight forwardly from this that the release of spectrum to mobile use to facilitate mobile broadband becomes a major priority for the UK.

1.2 Ofcom Public Sector Spectrum Release (PSSR): Technical coexistence issues for the 2.3 and 3.4 GHz award, consultation February 2014

http://stakeholders.ofcom.org.uk/consultations/pssr-2014/

In and of itself, this consultation adds relatively little, except to signify the continuing progress in the release of the bands, and the increasing certainty of a future auction, with various problems being addressed and resolved. It also includes a useful timetable. This might be seen in contrast to the 800 MHz and 2600 MHz spectrum release process, which for a multiplicity of reasons was very prolonged. Ofcom notes:

> *"1.3 We propose to conduct a market led award of the spectrum through an auction process. We anticipate the bands will attract interest from mobile network operators looking to use the spectrum for high power 4G mobile, using technologies such as Long-Term Evolution (LTE)."*

"15.2 The publication of this consultation should be viewed within a broader context of progress towards the award. It sits alongside a number of other events:

- *Around March 2014 we expect the European Commission's Radio Spectrum Committee to confirm a CEPT decision to identify TDD as the preferred channelling arrangement at 3.4-3.6 GHz (i.e. including the 3.4 GHz award band) throughout Europe – but with FDD as an alternative for those administrations which would prefer to use it.*

- *Around April 2014 we intend to issue the statement on amateur use in the release bands (2.3 and 3.4 GHz) and adjacent spectrum bands.*

- *Around June 2014 we expect the European Electronic Communications Committee to confirm a draft decision setting out harmonised technical and regulatory conditions for the 2.3 GHz band based on TDD channelling arrangements only. This would not be binding on member states. However there may be a subsequent binding EC Decision based on this work around 2015*

- *In summer 2014 we intend to consult on proposals for auction design – including auction rules - and on non-technical licence conditions. The latter will be informed by responses to our earlier Call for Inputs on those aspects of the award.*

- *In spring 2015 we expect to be in a position to publish a full statement on auction design and technical coexistence issues, plus our Information Memorandum for the 2.3 and 3.4 GHz award.*

- *Between autumn and winter 2015 – on currently anticipated timelines – we could commence an auction process. This would be in line with the MoD's intention that an award process would be completed in the 2015/16 financial year, as set out in a press release of September 2013."*

1.3 Ofcom Annual Plan, March 2014.

http://www.ofcom.org.uk/about/annual-reports-and-plans/annual-plans/annual-plan-2014-15/

The 2014/15 annual plan states as Strategic purpose 2 for the year, under the heading of "*secure optimal use of spectrum*":

"*Prepare for the award of the 2.3GHz and 3.4GHz bands and for the potential change of use of the 700MHz band"*

1.4 Ofcom spectrum management strategy Statement, April 2014

http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/

In the executive summary, in table 1 on page 5, Ofcom lays out its priority areas. The first three are:

- Priority 1 is *"addressing future mobile demands, recognising the importance of improving mobile coverage, and the availability of new mobile services*"
- Priority 2 is "*implementing our strategy for the 700MHz band" i.e. the release to mobile*
- Priority 3 is "*supporting the Government's public sector spectrum release programme*"

The executive summary then goes on to say:

> *"1.10 Our key objective when managing spectrum is to deliver its optimal use, meaning the use that delivers the greatest value to UK citizens and consumers"*
>
> *"1.9 We therefore expect to see:*
>
> - *a continuing emphasis on re-purposing the use of some spectrum bands as an important means of addressing changing spectrum needs. At the same time frictions between the long timescales often required to enable change of use and the fast pace of technology developments are likely to persist."*

Table 2 then fleshes out the work programme to achieve these priorities. The first three sections are as follows:

Table 2 - Work programme in support of our priority areas

Priority area	Issues that Ofcom is already considering	Issues that are likely to become relevant within the next 5 years	Issues potentially relevant over the longer term
Mobile data, mobile coverage and availability of new mobile services	• Preparations for WRC-15 (especially AI 1.1) and other ongoing international engagement • Developing a long term perspective on demand and supply options • Assessing the potential role of licence exempt and sharing approaches and implications for the supply balance • Monitoring progress in mobile coverage and networks' performance	• Considering harmonisation opportunities for UK spectrum use opened by international decisions • Applying our approach to assessing and enabling use of additional spectrum for mobile data as relevant • Exploring options for the further extension of geographical coverage of mobile voice and data services	• 5G technology evolution: consideration of new equipment standards and potential impact on spectrum requirements
700 MHz strategy implementation and the future of free-to-view TV	• International engagement on 700 MHz harmonisation and coordination discussions • Initial Cost Benefit Assessment on 700 MHz re-purposing for consultation • Explore opportunities to reduce and avoid future disruption of DTT platform • Engage with industry on role of DTT and the future of free-to-view TV • Participating in international discussions on the longer term future of spectrum at 470-694 MHz	• Final decision on 700 MHz repurposing If appropriate thereafter: • 700 MHz award design if relevant • Work with interested parties to prepare for changes and to monitor progress • Develop detailed plans, set up delivery structures and implement regulatory steps required to enable transition • Monitor developments in market and regulatory developments including TV distribution technologies and implications for the long term role of DTT	• Enabling action and regulatory support to 700 MHz clearance and award, if appropriate
Supporting the PSSR programme	• Undertaking the auction of the spectrum vacated by MoD at 2.3 and 3.4 GHz • Supporting the government on sharing opportunities	• Supporting the government's considerations of mechanisms to secure efficient use of spectrum by public bodies • Leveraging our experience on spectrum sharing into Public Sector spectrum • Moving towards unified information on spectrum usage and frequencies available for shared access across civil and crown holdings	• Supporting the government in future releases

Deeper into the document, we find the following:

"3.5 Growing demand for mobile data will have important implications for the management of spectrum over the next decade. A greater proportion of the population can now afford, and choose to buy, internet-enabled wireless devices such as smart phones and tablets. Thus a growing proportion of the population uses mobile data services, and each user tends to consume more data. The rising popularity of over-the-top services, including on-demand video, is likely to sustain mobile data consumption over time. These trends could see the volume of data consumed over mobile networks grow by many orders of magnitude; recent analysis for Ofcom suggested a central estimate of demand in 2030 might be of 80 times the 2012 level, although projections of this growth rate are subject to high levels of uncertainty. Moreover, demand will be highly concentrated in urban, hot-spot locations, placing even greater pressure on spectrum access at these locations. As the consumption of mobile data grows, consumer expectations around widespread data coverage are also likely to increase."

And:

"4.6 We consider that, in general, the optimal use of spectrum is most likely to be secured for society if spectrum is used efficiently, that is if it delivers the maximum benefits (or value) for society. The total value to society from spectrum use derives from two broad sources of value, namely, private value and wider social value as depicted in Figure 2 below.

Figure 2: Components of value to society from spectrum use

4.7 The private value of spectrum use is the value (for the consumer and service provider) generated as a direct result of the use that is made of it. The wider social value of spectrum use is the value (for others) that is generated indirectly, or as a by-product of the use that is made of it.

4.8 When considering the benefits (or value) of spectrum use, therefore, we consider all sources of value, whether or not these can be monetised (i.e. can be captured in the price that is paid for the service provided). These additional sources of value include the indirect benefits ("wider social value") that society derives from the use of spectrum (e.g. as a result of increased social cohesion, or the plurality of the media). Whilst putting a value on the indirect value of spectrum use can be challenging it is still possible for robust decisions to be reached on the basis of a qualitative assessment of the relative wider social value of services."

"5.8 Demand for mobile data is likely to continue to increase significantly in future. As demand for capacity generated by handheld devices increases, expectations of ubiquitous data coverage are also likely to become increasingly relevant.

5.9 There have been a range of predictions of future demand for mobile data, and we acknowledge that any long term forecasts in this sector will have a high degree of uncertainty. However, the potential scale of this challenge, the potential benefits that could be achieved by meeting it, and the long lead times normally associated with changing spectrum use, where appropriate, mean that maintaining a forward looking perspective on these issues is a priority for us.

5.10 There are a range of potential solutions to meeting the mobile data challenge, including the use of more efficient technologies and greater use of small cells. However, additional spectrum is likely to be a one component of the relevant mix of future solutions. This spectrum could be made available through spectrum re- purposing or spectrum sharing (e.g. where the use of the spectrum could be for off-loading data from mobile networks, including Wi-Fi off-loading)."

The obvious issue that arises from these points in the present context is whether setting a higher or lower charge for 900 MHz or 1800 MHz spectrum fees is likely to raise or lower the total social value that can be obtained from the use of spectrum. It follows that:

- if the level of consumer benefit is related to the level of data traffic that is consumed,
- and that no more data can be consumed than the mobile operators are able to supply,
- then the industry position that makes most likely the provisioning of the maximum supply and hence maximum consumer benefit is one where the costs of that provision are minimised

As we discussed in annex 3.1 of the present consultation, sadly lacking from Ofcom's evaluation of the level of spectrum fees is any impact analysis, in relation to this specific point – i.e. the level of spectrum fees that maximises consumer benefit, whilst still satisfying the broad range of possible views of "full spectrum value".

The statement then goes on to say:

"5.11 Any future spectrum re-purposing for mobile data use could involve significant costs and disruption. We would expect to proceed with such repurposing only in cases where we considered that the incremental value of the new use was greater than the value associated with alternative or incumbent spectrum uses. If regulatory action is necessary to bring about such changes we would consider the case with reference to the full range of costs

and benefits associated with change of spectrum use, as well as consideration of all our duties."

"5.13 Our work in this area will cover three key areas: contributing to international debate and decisions, maintaining a long term perspective on changing UK demand and options to address this, and progressing our work on mobile coverage. ***This is in addition***[6] *to the work in the following two areas which have been identified as separate priorities in their own right and discussed below, but which are clearly relevant to mobile data:*

- *supporting the government in delivering its PSSR Programme and in particular the release of 2.3 GHz and 3.4 GHz by Ofcom; and*
- *implementing the 700 MHz strategy."*

"5.20 Over the coming years, we will need to maintain an informed view of how demand for wireless data continues to evolve, and how international, market and technology changes affect mitigation options for increasing mobile data capacity if this emerges. ***This will be crucial not only to sustain the current increasing benefits associated with growing mobile data use***[7]*, but also to ensure that any potential impacts on incumbent spectrum users, whose access to spectrum could be affected by accommodating more mobile use, are properly accounted for and managed.*

5.21 We are developing a mobile data strategy to help us understand how we can create options to address long-term growth in mobile data whilst taking account of other spectrum users. Two specific objectives are i) to inform the UK position in the important international debates on future mobile spectrum discussed above; and ii) to prioritise Ofcom's future spectrum work programme relating to mobile data. In doing this we are looking to the longer term and beyond the tranche of spectrum (including 700 MHz, 2.3 GHz and 3.4 GHz) already under detailed consideration.

5.22 As discussed above, the long term level of demand for mobile data is very uncertain and there is a range of ways that the capacity of networks can be improved in the future. At this stage we do not know how much additional spectrum it will be appropriate to make available for mobile data use in the long term. It is possible that only a small number of additional bands will be ultimately made available. However, we think it is important to undertake preparatory work to understand and, where appropriate, create the long term options for additional mobile data spectrum use.

5.23 Over time, we will keep the relative prioritisation of potential mobile bands under review. This will include monitoring market and international developments, as well as considering how evolving demand influences the relevant mix of supply options (including new technologies and changing

[6] Vodafone emphasis
[7] Vodafone emphasis

network topologies), as well as monitoring overall level of demand to assess the need for additional spectrum."

1.5 Mobile Data Strategy Statement, May 2014

http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/statement/

From the executive summary:

> *"This document is our long term strategy to address the increasing use of data by mobile devices like smartphones, tablets and laptops. UK citizens and consumers already benefit considerably from use of mobile devices and the data traffic consumed by those devices is expected to grow significantly in the future.*
>
> *There are a number of ways to increase the capacity of mobile networks to deal with this growth, such as more efficient technology and greater use of small cells, but use of additional spectrum is likely to be part of the solution. We are already preparing to award suitable spectrum in the 2.3 GHz and 3.4 GHz bands and are today consulting on a proposal to release the 700 MHz band for mobile use. However, the potential scale of the future challenge, the potential benefits that could be achieved by meeting it, and the long lead times normally associated with changing spectrum use, mean that developing a long term strategy is important.*
>
> *This document therefore identifies additional spectrum bands for potential mobile use and prioritises our efforts on these. It describes what we plan to do to better understand the possibilities for each band, and, where appropriate, ensure there is an option for future mobile use.*
>
> *We will take forward the band-specific actions identified in this document and continue to develop our understanding of future demand and technology trends. We will update and refine our strategy periodically as necessary."*
>
> *"1.2 Use of mobile data services brings considerable benefits to UK citizens and consumers and demand for these services is likely to increase significantly in the future. One estimate is that demand for mobile data in 2030 could be 45 times higher than today, with the traffic carried on mobile networks (after allowing for traffic offloaded to Wi-Fi networks) increasing 25 times. Addressing this demand is a priority area for our work over the coming 10 years."*

Much of the discussion of the relevant bands is similar to the spectrum management strategy statement, but in table 2 there is an illustrative quantification of the potential increase in spectrum available for mobile data downlink, from 290 MHz in 2014 to 491 MHz in 2016 (169% of the 2014 base), to 671 MHz in 2022 (231% of the 2014 base) to 941 MHz in 2028 (324% of the 2014 base). Arguably this understates the potential growth, since it includes in the 2012 base the existing 900 MHz spectrum, whereas in

fact as Ofcom has established the 900 MHz band cannot be currently used for LTE services in the UK – its deployment for this purpose is still somewhat deferred.

Table 2: Illustrative implications for spectrum availability

Scenario	Bands available for mobile data		Total MHz available for mobile data (downlink estimate)
2012	• 900 MHz, 1800MHz	• 2.1 GHz	162 MHz
2014	*As 2012 plus:* • 800 MHz	• 2.6 GHz	290 MHz
2016	*As 2014 plus:* • 2.3 GHz, 3.4 GHz	• 1452–1492 MHz	491 MHz
2022	*As 2016 plus:* • 700 MHz • 2 GHz MSS	• 3.6-3.8 GHz • 1427-1452 MHz	671 MHz
2028	*As 2022 plus:* • 2.7-2.9 GHz	• 3.8-4.2 GHz • 1492-1518 MHz	941 MHz

1.6 Consultation on future use of the 700 MHz band - Cost-benefit analysis of changing its use to mobile services, May 2014

http://stakeholders.ofcom.org.uk/consultations/700MHz/

This document puts flesh on the bones of the Spectrum Management Strategy Statement, by producing a quantification of the possible benefits to consumers for 700 MHz in mobile use rather than in DTT use. It uses as a proxy for the consumer benefits of mobile use a cost model that identifies the cost saving to operators that could arise from their use of 700 MHz spectrum to provide additional capacity for mobile data services, but then goes on to estimate further consumer benefits on top of this, using the same cost estimates as a proxy for these additional benefits:

- *"Reduction in costs of meeting increased demand for mobile data capacity from having to build and to operate fewer network sites"*
- *"Improvement in the performance that mobile users would experience particularly deep indoors and in rural areas, also measured as the reduction in costs from having to build and to operate fewer network sites to achieve the improved performance"*[8]

These items are very clearly identified as a consumer benefit – i.e. if the operators are able to avoid these costs, they will be able to provide capacity to allow this demand to be satisfied. Furthermore table 1 continues with an overall assessment of the benefit:

> "*Reductions in consumer prices: a significant proportion of these network cost savings would likely be passed on to consumers*"

[8] From table 1

Quite obviously such network cost savings can only be passed on to consumers to the extent that they exist. To the extent that the network cost saving is merely re-expressed as spectrum costs that the operators are obliged to pay, then any such cost saving benefit is lost.

On top of this table 1 then identifies further unquantified benefits, concluding that there is the "*potential for significant upside over and above the quantified benefits*".

This overall discussion points towards the view point that the use by UK citizens and consumers of as much mobile data traffic as possible provides a social and economic benefit to the UK. The Ofcom 700 MHz model provides a useful way to identify the likely level of such benefits. It is less clear that the model can be used to provide an indicator of the likely level of fees that operators should pay to secure use of the spectrum, given that the higher the level of operator costs is set, the less able operators will be able to provide incremental capacity. We return to this point in section 2 of this annex.

1.7 **Variation of UK Broadband's 3.4 GHz Licence, June 2014**

http://stakeholders.ofcom.org.uk/consultations/uk-broadband-licence/

This, whilst related primarily to adjacent spectrum, contains continuing confirmation of the release of the 3.4 GHz spectrum:

> *"1.19 It is possible that such an outcome could be achieved after the planned 3.4 GHz auction through spectrum trading. However, we are also interested in exploring the potential for this to be addressed through the design of the PSSR award process.* ***We will consult on the design for the PSSR 3.4 GHz auction in the autumn of 2014****."*
>
> *"3.12 A total of 150 MHz of radio spectrum within the 3.4 GHz band is being released by the MOD to Ofcom for licensing. This released spectrum comprises frequencies in the range 3410-3600 MHz (excluding the 40 MHz held by UK Broadband). This additional 3.4 GHz spectrum forms part of the Public Sector Spectrum Release (PSSR) programme, which aims to free up 500 MHz of public sector spectrum for civil use by 2020.*
>
> *3.13 The 3.4 GHz award is likely to be attractive to mobile network operators looking to use the spectrum for high power applications such as Long Term Evolution (LTE) mobile broadband. The MOD has asked Ofcom to award licences to use these radio frequencies in 2015/16. We intend to conduct a market led award by use of an auction process."*

1.8 Ofcom consultation on the UK preparations for the World Radiocommunication Conference 2015 (WRC-15), June 2014

http://stakeholders.ofcom.org.uk/consultations/wrc15/

This document emphasises the continuing attention of Ofcom to the issue of harmonisation of suitable mobile broadband spectrum so that it can be released in the UK when needed.

> *"1.8 Mobile broadband (including Wi-Fi): One of the highest profile issues is how to address the increasing use of data by mobile devices. We have recently set out our long term strategy to address this which identified a number of bands for further work. The WRC presents an opportunity to start identifying the bands that can potentially be harmonised, allowing for the lead time required for equipment to be developed and services to be rolled-out. As part of this, the European and international working groups preparing for the conference have carried out studies to assess technical compatibility with existing services in a number of frequency bands and will then make proposals for specific bands.*
>
> *1.9 Ofcom is very actively engaged in these discussions at both an international and European level. We recognise that it is not always easy to project future demand for mobile broadband, and want to ensure that international decisions allow us to react to future growth in demand if and when needed."*
>
> *"Agenda Item 1.1 - Additional allocations for Mobile (IMT) services and applications*
>
> *4.2 Agenda item 1.1 addresses additional spectrum allocations for mobile services that would be used by IMT19 and other terrestrial mobile broadband applications (e.g. smartphones, tablet computers, Wi-Fi services). The proposal is to increase, at an international level, the spectrum allocations available for mobile broadband services. This agenda item has had the highest profile in the lead up to WRC-15, not least as it potentially affects many of the other radiocommunication services."*
>
> *"4.4 We believe that there is a need for sufficient spectrum to be allocated to mobile and/or identified for IMT at the international level to give us the flexibility at national level to decide when and where to release harmonised spectrum for mobile broadband* ***as we believe there is a risk that the spectrum currently available for mobile use may not be sufficient to meet future demand***[9]*. Given the long lead time needed to change the use of spectrum, our preliminary conclusion is that additional mobile allocations and/or identification of bands for IMT at WRC-15 will be beneficial. We will keep this situation under review and will continue to develop our view of future growth in mobile data demand and potential spectrum implications, recognising the degree of uncertainty associated with such analysis."*

The document then supplies a very similar list of candidate bands to those identified in the Mobile Data Strategy Statement, identifying what needs to be done for each to permit harmonisation for mobile use.

[9] Vodafone emphasis

1.9 Summary

There is thus very considerable continuing evidence of the likelihood of the release of additional spectrum in the future. This can only exert a downward pressure on the value of existing spectrum such as 900 MHz that can be used to provide incremental LTE capacity, given the wider range of choice of alternative spectrum that this additional supply provides.

We would agree with Ofcom (paragraph A9.9) that in reality many of the potential additional bands can only be released some time into the future – but it is important to remember that what is being attempted in the present context is as a minimum a 20 year valuation of the spectrum – of relevance therefore is not simply present traffic levels, but the very uncertain future traffic levels, which will exceed current levels by an unknown factor. The present view is that the additional spectrum beyond Ofcom's current priorities of 2.3 GHz, 3.4GHz and 700 MHz will only be needed some time in the future, but such deferred usage is common to all incremental spectrum – the basis of its value lies not in costs that can be immediately avoided, but in the total of costs that may be avoided over the next 20 years, by the use of adding capacity through spectrum rather than additional site build.

As we discussed in annex 8 of our previous submission, cost modelling can provide a useful illustration of the diminishing value to an operator of successive incremental spectrum such as 900 MHz, as opposed to the core spectrum of 800 MHz in that it avoids an increasingly lower level of cost, particularly in present value terms. We consider this in more detail in section 2 below.

Section 2 Cost modelling and willingness to pay insights

Ofcom has briefly considered in Annex 9 of the Second Consultation the possibility of using cost modelling to provide an alternative source of forward looking spectrum value, but has rejected it on the grounds that such modelling will produce a wide range of possible valuations, in particular given the uncertainty of modelling assumptions, especially of data traffic volumes over the next 20 years.

> *"In general, we recognise the value of technical modelling, and clearly this is a source of information which Ofcom has employed in numerous circumstances. However, as set out in the October 2013 consultation, such modelling is highly sensitive to the range of assumptions that need to be made, such that we considered that an attempt to derive point estimates of value based on this approach would be of limited additional benefit in deriving our proposals on ALF.[10]"*

Ofcom has attempted to adapt the 700 MHz model that it used to estimate the consumer benefits of transferring 700 MHz spectrum from DTT to mobile use to determine an appropriate value for spectrum. It obtains a very wide range of results from this of "*between zero and £138m per MHz*"[11] and concludes that:

- "*Overall we do not believe the adjusted 700 MHz model is well suited to modelling the value of 900 MHz spectrum*"[12]

- "*The example above illustrates some of the difficulties of network cost modelling in deriving reliable estimates of the value of spectrum to individual operators. Any such model will be subject to significant uncertainty about appropriate parameter assumptions, leading to valuation estimates that vary over a wide range*"[13]

We recognise the difficulty Ofcom experienced in attempting to use a model created for one purpose i.e. the identification of the level of consumer benefit arising from the use of 700 MHz for mobile broadband, for another very much different purpose i.e. the sums operators should pay for the use of the 900 MHz.

However Vodafone does not entirely agree with Ofcom's second point. The 700 MHz model's unsuitability for modelling the value of 900 MHz spectrum fees is not a problem that could not be addressed by the use of an alternative, specifically purposed model. Such a model would we believe generate a significantly lower set of spectrum values than £0m to £138m even when using a methodology similar to the 700 MHz model.

But most importantly, we consider that consideration of the cost modelling approach can yield three useful insights to the valuation of spectrum, none of which Ofcom has properly taken into account in the present consultation.

[10] A9.11 of the further consultation
[11] A9.16 of the further consultation
[12] A9.25 ibid
[13] A9.26 ibid

- Irrespective of the absolute values output by the model there is one straightforward observation that can be made from the way the 700 MHz model functions and has been used to provide illustrative values of 900 MHz. This is that the model makes very much more use of 800 MHz spectrum than 900 MHz – the former is core spectrum, the latter is incremental spectrum. 800 MHz spectrum is used earlier than 900 MHz, and much more extensively – i.e. immediately at LTE launch, and as a very key spectrum band for full national coverage. Vodafone has not seen the adapted 700 MHz model, but we would expect that 800 MHz spectrum has been deployed at every macro site, as soon as LTE service commences. The use of 900 MHz spectrum is later in time and as Ofcom explains is considerably less geographically extensive. This immediately implies that the present value to the operator of 900 MHz must be very much less than 800 MHz, both confirming the substantial value discount implied in the international benchmarking and suggesting that this in fact may be insufficient.

- Ofcom's stated policy of positioning itself to release additional spectrum beyond the currently planned 2.3 GHz, 3.4 GHz and 700 MHz effectively takes off the modelling table all scenarios of high data growth with no additional spectrum release. It is these scenarios that produce the highest spectrum values from cost modelling – therefore Ofcom's stated policy provides a powerful cap to the reasonable level of spectrum value: this is a factor that should be recognised by any suitable cost model (and is not recognised in the reported range of the 700 MHz model's outputs).

- Ofcom's tentative cost modelling is based around the possible cost of the alternative to spectrum, i.e. the incremental network investment that is necessary to support the incremental traffic demand in the absence of additional spectrum. However it says nothing as to whether such investment will actually occur – i.e. whether the incremental revenue that may arise from the incremental capacity increase can be expected to be greater than the level of investment (with or without incremental spectrum), or whether such investment will prove to be beneficial to the UK economy. Proper consideration of this point, given the limitations of consumer willingness to pay and the benefit to the UK from maximising mobile data consumption[14] will lead to an appreciation that this will impose a downward impact on the value of spectrum for fee setting purposes. In order to maximise the societal benefit from mobile data traffic, only the lower levels of outputs from a cost modelling exercise of the 700 MHz model type can be appropriate to be adopted for spectrum valuation.

We consider these points in the sections below.

The adaptation of the 700 MHz model

[14] As per the comments of Ofcom and DCMS in section 1 above, e.g. at 1.1, 1.4 and 1.6

We agree with Ofcom that technical modelling can be a useful source of information for spectrum value, and suggested in our previous consultation response that given Ofcom's development in 2013 of a model for considering the benefits of 700 MHz mobile use, a model could be relatively similarly developed for 900 MHz that could provide meaningful information.

However Ofcom's illustrative adaptation of its final 2014 700 MHz model is not such a purpose built model, and in itself as a consequence it is not particularly helpful, and nor is the way that Ofcom has attempted to use it. The primary purpose of the present 700 MHz model is to provide a view of the consumer benefits of mobile use of the 700 MHz band, rather than retaining it for DTT use. The model attempts to derive the potential value to consumers by the use as a proxy for this of the costs that could be avoided by the network operators if 700 MHz were available to them. This approach is necessarily rather different from the needs of the present case.

Ofcom provides only very limited information as to what it has done in its adaptation of the 700 MHz model, so our analysis is also somewhat limited. Like Ofcom we do not believe that the outputs shown in table A9.2 that give a range of possible values for the period 2015 – 2034 of between £0m and £138m per MHz can in any way be considered helpful for informing the level of spectrum fees:

> *"A9.21 Therefore, there is a significant risk that the structure of the model, which was designed for a different purpose, is not well-suited to modelling the value of 900 MHz to specific individual operators."*

Apart from anything else, the Ofcom 700 MHz study concluded that the likely savings for operators were approximately £480m to £770m for 2 * 30 MHz of 700 MHz spectrum. This would appear to be equivalent to £8m to £13m per MHz i.e. very different from the range suggested for 900 MHz of up to £138m per MHz – admittedly this is over a different 20 year period and would need adjusting for proper comparison, but it is one (approximately 2020 – 2040) with higher levels of total data traffic than the period Ofcom used for 900 MHz evaluation (2015 – 2034).

We can readily see that there are as a minimum the following issues with Ofcom's use of the 700 MHz to generate possible 900 MHz values:

- An assumption that 900 MHz can be used for LTE immediately in 2015. This contradicts Ofcom's own conclusion from the previous consultation that LTE use of 900 MHz was still somewhat deferred. As a result of this substantially advanced timing, we presume that the model is assuming that 900 MHz becomes a major capacity and coverage LTE network component immediately in 2015, and is thus permitting the avoidance of significant site build costs from 2015 onwards. This is unrealistic. In reality 900 MHz availability for LTE will be later, and will happen only after the full LTE national roll-out is complete, and not before – so the additional spectrum will only be relevant to providing additional capacity over and above a base of say 17,500 plus sites.

- An assumption that a significant proportion of network traffic, 18 - 22% can **only** be carried on sub 1GHz spectrum. We accept that there may be some inverse relationship between frequency and value, but this is relative, not absolute – rather, a slightly more dense macrocell network or more small cells may be the network design consequence of a lower volume of low frequency spectrum (but in practice the initial coverage network of 17,500 plus sites may be sufficiently dense to have already largely extinguished such frequency differentiation in high traffic areas). This is particularly so with LTE where bandwidth volume rather than specific frequency is emphasised. Ofcom comments on this assumption in the following terms:

  > *"A9.18 In fact, both EE and H3G offer mobile broadband services today using little or no sub-1 GHz spectrum. This could be taken as evidence that operators without significant holdings of sub-1 GHz spectrum can adapt their commercial strategies to mitigate the coverage and performance disadvantages they face as a result of their predominantly higher-frequency spectrum holdings."*

  The point is obviously deserving of some analysis before constructing a 900 MHz value model. Very evidently the apparent bid strategies of EE and H3G in the Auction would not seem to bear out Ofcom's assumption of the criticality of maximising sub 1 GHz holdings.

  The 18 - 22% assumption lies behind a significant component of the sizes of the apparent outcomes of the cost modelling – this is confirmed by Ofcom in paragraph A9.20, where it is suggested that a less than halving of the size of the absolute bar leads to a more than halving of the resulting spectrum value.

  Ofcom's conclusion appears to suggest that the assumption may not be appropriate in the present context. We assume that correcting for it would very substantially reduce the range of reported spectrum valuations. We also find it inconsistent with this 18 – 22% proposition that Ofcom could assume in the MTR charge control than the average efficient operator of 2G uses 1800 MHz spectrum and of 3G uses 2100 MHz spectrum, yet apparently continues to consider that sub1 GHz spectrum holding is essential for spectrum valuation purposes.

- We discuss in annex 1 in connection with Ofcom's marginal bidder analysis whether it is appropriate for Ofcom to consider that EE would be allowed to increase its spectrum holding before additional spectrum is released – the adapted 700 MHz model is deriving a value of 900 MHz spectrum on the basis that EE is allowed to extend its dominant position in 2015. It is not at all clear that this is a correct view to take.

- We note that Ofcom is using 2 * 5 MHz as its increment in the cost modelling – whilst we believe that this may be an appropriate increment to use for an existing operator, this is not the volume of spectrum that Ofcom has adopted in

its marginal bid analysis in determining an 800 MHz value from the Auction, where apparently 2 * 10 MHz has been used as the increment. There is a clear inconsistency. Given that from our previous review of the 2013 version of the 700 MHz model it was explicit from the outputs that a larger volume of incremental spectrum led to a lower average value per MHz, we would expect that 2 * 10 MHz of 900 MHz spectrum would give a rather lower value per MHz from the 700 MHz model than 2 * 5 MHz apparently does.

- It is not clear whether all of the assumptions used in the latest MTR modelling version have been adopted – it may be that the model continues to use assumptions from the previous MTR model, that have been replaced or superseded by the latest generation of MTR modelling.

All of these factors suggest that the range of absolute values for 900 MHz suggested by the 700 MHz model is too high – whilst obviously the indicated floor value of £0m cannot change, the quoted ceiling of £138m would, on a more realistic set of inputs, be very substantially reduced.

We ultimately agree with Ofcom that this particular modelling exercise sheds no useful quantified light on setting the absolute level of ALF. But this does not mean that cost modelling is always of no merit. Ofcom's conclusion is specific to the present 700 MHz model, rather than a general one that cost modelling is of no benefit. An alternative model, purpose written could have shed rather more light on long run spectrum values.

We would have expected that a model built for the purpose of 900 MHz spectrum valuation would have addressed some of the issues identified above somewhat differently and come up with a significantly lower range of values, even using Ofcom's range of scenarios. We consider however that the larger problems with the "as is" 700 MHz model are likely to fall into two categories:

- the use of too wide a range of traffic volume and spectrum volume scenarios, and
- an implicit assumption that the point of indifference between investment in more cell sites and investment in more spectrum is the right level of fees for operators to pay.

As a result of this, whilst the 700 MHz model, however imperfectly, may give some form of measure of what additional traffic capacity might be capable of being supplied if the spectrum were made available, and at what level of incremental investment, it cannot be expected to give a meaningful view of the underlying forward looking value of 900 MHz spectrum suitable for the setting of spectrum fees.

We address these issues below, but first consider the point of the difference in relative intensity of use of 900 MHz versus 800 MHz in the cost model, and the implications of this for relative spectrum valuation.

Relative use of 800 MHz and 900 MHz in Ofcom's 700 MHz model

In its use of the 700 MHz model, Ofcom details in annex 9 some of the assumptions adopted as to how 900 MHz spectrum might be used for LTE, in order to produce an indicative value for the band. In particular it assumes first deployment of the band in 2015, and that deployment is only on 15% of macrosites in 2015. What we do not know is the proportion of macrosites on which 900 MHz is subsequently assumed to be deployed – but it would appear that 15% may be modelled as a constant - and it is unclear what penetration rate Ofcom has assumed for 900 MHz capable devices in order to make use of the additional capacity being installed.

In contrast however, 800 MHz is deployed in the model, as far as we can tell, on all macro sites from 2013, and it is likely that Ofcom has assumed that all LTE devices are 800 MHz capable. Ignoring the unrealism of the assumption of early timing of 2015 for 900 LTE use already discussed above, it is still clear from the way that the model functions that the 800 MHz spectrum of the modelled operator is being deployed and loaded with traffic much earlier and more extensively than 900 MHz spectrum. Very obviously 800 MHz is being used to a considerably greater extent than 900 MHz spectrum, which is used later in time, less intensively, and only at a sub-national level.

Ofcom's method in the cost model is to consider the value of the incremental band as a PV calculation based on 20 years forward looking use; in such a PV, as a result of discounting, more weight is given to the immediate future than to the end of the 20 year period. The differential relative use of the 800 MHz and the 900 MHz bands in the model thus immediately points to the fact that 800 MHz spectrum must have a value in use in PV terms considerably greater than that of 900 MHz spectrum. So irrespective of the absolute level of value that the cost model can produce for an increment of 900 MHz, it is very clear that the model would produce a significantly higher absolute value for an increment of 800 MHz.

The clear implication of the way the model is using the two spectrum bands must be that 900 MHz can only be valued at a substantial discount to 800 MHz. This obviously echoes and supports the international benchmarking evidence. Quantification of any relative value from the cost model has not been attempted and would be difficult to carry out, but given the very obvious lower use made in the model of 900 MHz vs. 800 MHz, it would be expected that the 62% value suggested from Vodafone's analysis of the benchmarking data is on the high side of what a suitably developed cost model might provide.

To Vodafone this is not a surprising conclusion. We examined in some detail in annex 8 of our previous consultation the reasons why 900 MHz can be expected on a current, forward looking view to have a significantly lower value in use to mobile operators than 800 MHz and do not repeat the arguments here. Fundamentally 800 MHz is core LTE spectrum, that can be (and has been) brought immediately into use from 2013 on a national basis. 900 MHz is incremental LTE spectrum, likely to be used later in time, less intensively (and initially by a less than 100% proportion of LTE devices) and at a sub-national level. This is exactly in alignment with the way we believe Ofcom has modelled the use of 900 MHz in its 700 MHz model.

In the sections below we consider the other insights on spectrum value that can be derived from a cost modelling approach and method.

Valid future mobile traffic demand and spectrum volume scenarios

The biggest single uncertainty generating a value from a cost model of the 700 MHz model type for the value of incremental 4G spectrum over a future 20 year period very clearly relates to the estimation of the level of demand for data traffic.

It is a matter of general agreement that the volume of mobile data traffic will rise, but how far and how quickly is a matter of conjecture. This is amplified by several related issues, amongst which are the following:

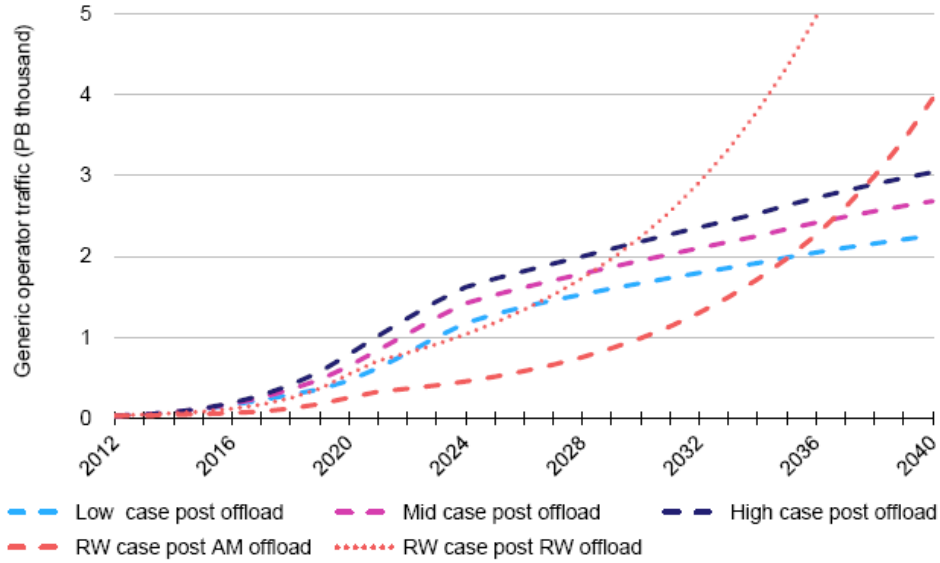
- Traffic on a mobile device can be delivered via wi-fi offload, when the device is not in transit between wi-fi capable locations.
- Furthermore where the consumer possesses multiple devices that can satisfy a particular data demand (PC, laptop, TV, internet TV, tablet, smartphone etc.) the consumer may be relatively indifferent as to which device a particular service is actually delivered on (except on price grounds) e.g. IPTV on a TV, a tablet or a mobile.
- The choice of which device and which delivery method to use may come down in part to the retail cost of delivery.
- The price/volume structure of wi-fi data is very different from that of mobile (both in terms of retail rates and underlying network costs) – the former is to a large extent independent of volume, whereas mobile capacity increases are much more closely linked with increases in the cost of provision.
- Estimates as to the proportion of mobile device wi-fi offload vary – the mobile data volume (i.e. data delivered on a mobile device through the mobile network) is very sensitive to such assumptions.
- The willingness of consumers to pay for the contemplated substantial increases in mobile data volumes is unclear.
- There is very little baseline of established data use to draw on.
- Any valuation of spectrum needs to look at usage projected forwards at least 20 years

Inevitably, there is wide divergence in the estimates produced by various bodies, particularly beyond the next decade, where extrapolations of mobile data growth become especially difficult, particularly in the context of alternative delivery methods and alternative devices that may satisfy the same demand. Once full mobile broadband device penetration is approached, how will the average mobile data usage

per device behave? Is there an S-curve or will the total mobile data usage continue to grow?

The data traffic forecast underlying the 700 MHz work illustrates some of the variability that has been forecast – but these are neither the highest or lowest forecasts that have been developed.

Figure 3.6: Modelled traffic forecasts, post offload[20] [Source: Analysys Mason, 2014]



The current uncertainty relating to the real level of the future growth of data traffic demand is not fundamentally different from the uncertainty that existed in 2013 – however the increasing confidence that spectrum will be made available in the future to match whatever the rising level of data demand that may be the actual outcome, has, other things being equal, driven down the range of valuations of spectrum that are possible.

Ofcom's stated policy discussed in section 1 above on providing additional spectrum for mobile broadband use beyond the existing priority bands, as described in the section above does in practice provide a cap on spectrum value. This is because the policy denies or at the very least substantially downgrades the possibility of a high data forecast with low future spectrum release – it is this permutation that gives rise to the highest valuation of spectrum. Put very simply a scenario with a high data traffic forecast but low additional spectrum availability is no longer tenable.

The OSAB minutes for 30th September 2013 (available online) explain the position very clearly:

> *"subject to the limitations and variabilities inherent in the study, the results indicated:*

- *high demand scenario: there was a case for additional allocation of around twice as much mobile spectrum (around 1 GHz) to be available from 2020 in the event of the demand scenario, despite the advent of small cells, offloading to Wi-Fi and improved spectrum efficiency*

- *medium demand scenario: the case for substantial extra allocation is much reduced, with an excess need for 200-300 MHz from 2020*

- *low demand scenario: existing allocations should be sufficient"*

As a result of Ofcom's policy from the MDS, acceptable modelling scenarios that could be usefully adopted in any valuation model are generally restricted to:

- Higher data growth with varying levels of additional spectrum release beyond the currently in progress bands of 2.3 GHz, 3.4 GHz and 700 MHz.

- Lower data growth with no additional spectrum release beyond 2.3 GHz, 3.4 GHz and 700 MHz.

However, in its adaptation of the 700 MHz model, Ofcom would appear in its high scenario to have used a high traffic forecast with a low spectrum release forecast, and in its "central high" scenario to have combined a high traffic forecast with a medium spectrum release forecast – both of these permutations would appear to have been taken "off the table" by the MDS Statement. As a result, the cost modelling scenarios that give the highest possible spectrum value are no longer viable, and the potential range of outputs more limited (and on average lower).

Effectively therefore Ofcom's declared spectrum policy has not only reduced the value of mobile spectrum, but also placed a cap on the forward looking value of that spectrum that could be obtained from cost modelling.

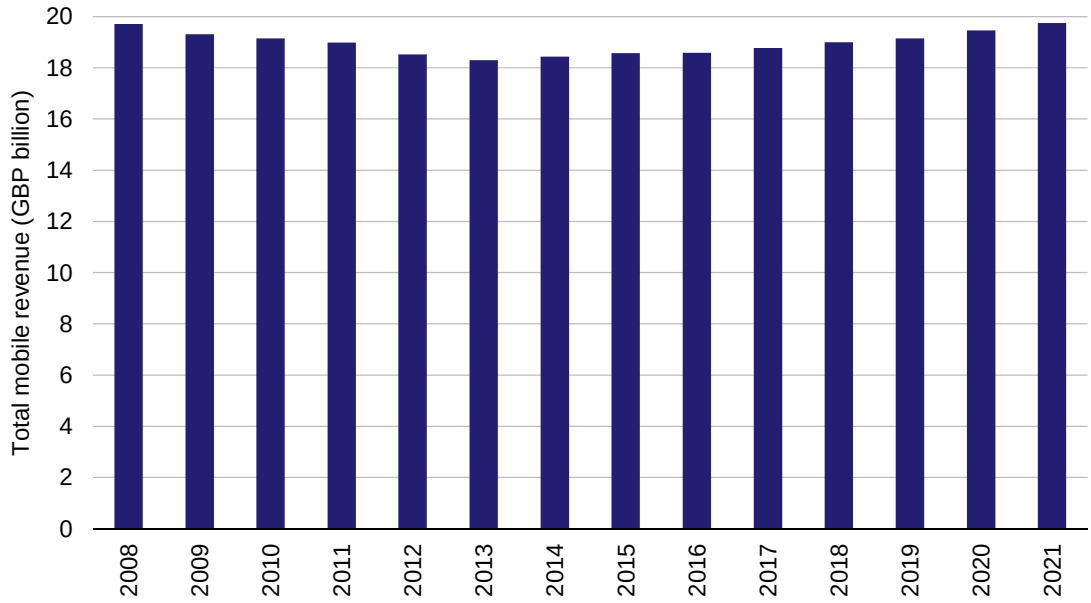
Willingness to pay for additional mobile data traffic

One important qualification to the generally published mobile data spectrum forecasts is the fact that they all largely ignore any consideration of consumer willingness to pay. It is implicitly and blithely assumed that either mobile data demand is perfectly price inelastic or that it is always possible for operators to supply the capacity to meet all forecast levels of demand with no increase in the total costs of provision. It is difficult to believe that either is likely to be true. There is no real consideration as to whether the level of forecast demand can actually be satisfied at a price that consumers might be willing to pay.

This cannot be always right – an assumption that the level of demand by consumers for mobile traffic will be independent of the operators' charges for that traffic is highly

unlikely[15]. Consumers' willingness to pay for additional data services is uncertain but very evidently is not linear to volume. It has been very clear in the last few years that mobile data traffic volumes are rising much faster than mobile data revenue. Analysys Mason, for example, in their review for the DCMS/BIS in 2012 on spectrum value[16], have projected roughly constant mobile service revenue in nominal terms:

Figure 1: Total service revenue – historical values and forecast [Source: Analysys Mason, 2012]



Yet at the same time, Analysys Mason was expecting a very great increase in the level of data traffic being supplied. If this were to be correct then the implications must be that consumers might in practice be forecast to only be willing to make use of the volume of data that could be supplied without requiring any increase in consumer payment – and this possibly might be expressed as a payment constant in nominal rather than in real terms. This can only mean that a low willingness to pay more for additional data exists.

As a working assumption, it would be reasonable to suggest that the lower the cost at which a given level of mobile data capacity can be supplied, the more likely it is that consumers will wish to make use of that capacity – or, the lower the total costs of provision, the more the level of total demand. In such a calculation, spectrum fees may become an input, not an output.

[15] Apart from anything else, the level of wi-fi off load from mobile devices, potentially a very significant influence on mobile traffic demand, is unlikely to be independent of the incremental cost of supply to the consumer of the alternatives of wi-fi vs. mobile traffic.

[16] Impact of radio spectrum on the UK economy and factors influencing future spectrum demand, November 2012

The provision of additional mobile data traffic capacity

There are obviously some factors influencing the supply of mobile data traffic that will have a downward effect on unit prices, e.g. falling unit prices and rising spectral efficiency (although to take advantage of the latter may require additional investment). However in the absence of additional investment beyond the present coverage deployment, the future rise in mobile data demand can be expected to rapidly hit a buffer once the capacity that is provided by the current network is insufficient to meet demand. In order to satisfy any future traffic demand above this level, the traffic growth needs to be preceded by additional investment to permit increases in mobile capacity, as long as such capacity can be provided within the constraints of profitability.

Increased capacity can be provided by a combination of additional investment and rising spectral efficiency at existing cell sites, deployment of additional cell sites, and the use of additional spectrum. The deployment of additional mobile broadband spectrum significantly reduces the future network investment that is necessary for an existing operator since, subject to the cost of that spectrum, additional capacity can be provided without necessitating additional new cell site construction.

Cost modelling of the type employed by the 700 MHz model (and its illustrative adaptation for 900 MHz valuation) can show the level of costs that might be used to increase capacity from one level to another, with and without additional spectrum. It might show therefore that an operator needs to incur a PV of investment of £Xm to expand capacity to achieve a given traffic forecast, or that it could save £Ym of this investment if it was instead able to use an increment of spectrum (at zero cost). The difference between the two levels of investment might be taken as some sort of evaluation of the benefit of the additional spectrum.

But in reality the 700 MHz model approach is measuring the point where the operator is indifferent to expanding capacity through network investment with and without additional spectrum – if the operator has to pay £Ym for the spectrum, then without the spectrum it will incur costs of £Xm, and with the spectrum it will incur network costs of £(X – Y)m but then has to pay £Ym for the spectrum, then the cost to the operator will be the same in either case.

We see that this may be a useful way of identifying by proxy the benefit of additional spectrum to consumers. But it says nothing about whether either alternative will give a positive return to the operator, i.e. whether the investment of £Xm (with or without additional spectrum) will be more, or less than the incremental revenue[17] arising from the increased traffic capacity that is enabled by the investment. Modelling of the 700 MHz model type is not in itself sufficient for this purpose. What is necessary would be to extend the model to not only consider the costs of supply, but also have reference to the revenue that might arise from that supply, i.e. to reflect the consumer willingness to pay.

[17] Or perhaps the revenue after deducting non-network costs

The role of willingness to pay for increments of data traffic

It would appear fairly obvious that there is an interrelationship between the level of willingness to pay and the level of data traffic that is possible – a high willingness to pay for a given volume of traffic will permit the operators to invest in capacity increases, through either additional spectrum or other means, whereas a low willingness to pay makes such investment unviable: a demand forecast in these circumstances would be more restricted in level, than under circumstances of greater willingness to pay.

It is possible to take this analysis further and to consider that any demand forecast only has validity as a forecast to the extent that it is capable of being economically satisfied – i.e. that sufficient capacity to meet the level of demand can be profitably provided by the operator at the price that the consumer is willing to pay.

We accept that construction of a cost model that would capture this may be more difficult than a model of the 700 MHz model type, but despite that, the evaluation of what such a model would have to consider leads to a straightforward insight – that if as would seem reasonable, consumer willingness to pay becomes a critical factor in determining the level of investment, and restricts it to particular level, then a greater capacity can be provided for that level of cost by substituting additional spectrum for incremental network investment, **providing that the operator pays for the spectrum less than is being saved by the use of such spectrum**. Spectrum fees might thus be considered an input into the supply/demand balance between the costs of supply and the willingness to pay.

We are not aware that Ofcom currently has a model that can attempt this calculation – such a model would also obviously be of value in any impact analysis, in attempting to give some insight as to the impact on consumer benefit of different levels of spectrum fees i.e. as to whether setting a higher or lower charge for 900 MHz or 1800 MHz spectrum fees within the wide range of values that potentially could be described as "reflecting full market value" is likely to raise or lower the total social value that can be obtained from the use of spectrum.

As we discussed in annex 3.1 of the present consultation, sadly lacking from Ofcom's evaluation of the level of spectrum fees is any impact analysis in relation to this specific point – i.e. the level of spectrum fees that maximises consumer benefit, whilst still satisfying the broad range of possible views of "full spectrum value".

Quite clearly one of Ofcom's major objectives in spectrum management is to maximise consumer benefit from mobile data usage. This insight from the willingness to pay analysis is that benefit will most likely be maximised by enabling operators to maximise capacity via additional spectrum availability, to the limit of profitable provision of such capacity. The alternative would be to risk spectrum being unused and potential demand unsatisfied. To the extent that consumer willingness to pay will restrict operators' ability to provide capacity to meet or encourage the maximum possible level of demand, then this further reinforces the need for Ofcom to arrive at a conservative valuation of spectrum for spectrum fee payment purposes.

Summary

Vodafone's points made in this section:

- The acknowledged limitations of the 700 MHz cost model for the present purpose mean that the reported outputs are generally too high, and are of no use as absolute values for the purposes of 900 MHz valuation. However if the limitations were to be properly addressed, a very significantly lower range of values would be output from a specifically built cost model.

- But the relative intensity of use, even in the existing 700 MHz model, of 800 MHz over 900 MHz in the next 20 years, especially when considered as a current PV very clearly makes the point that the relative long run value of 900 MHz must be considerably lower than 800 MHz, reinforcing the international benchmarking observation of lower relative value but suggesting that the value of 900 MHz is likely to be very considerably lower than that of 800 MHz.

- The increasing certainty of availability of 700 MHz, 2.3 MHz and 3.4 MHz spectrum and also substantial additional spectrum as required collectively lead to a capping of spectrum valuation scenarios and this will also significantly drive down the reasonable range of values that can be produced from a purpose written cost model.

- The impact of low consumer willingness to pay for additional data traffic on the level of future network investment in additional capacity will also have a downward impact on the level of spectrum values suitable for fee setting, especially when considered in the context of maximising societal benefit from encouraging mobile demand. This would become clear in any properly constructed impact analysis - one that we consider to be necessary for the proper discharge of Ofcom's duties.

All of these point to the conclusions that the range of 900 MHz spectrum values that could be output from a purpose written cost model is much smaller and very considerably lower than Ofcom suggests, is also much lower than any value ascribed to 800 MHz spectrum, and that conservatism in spectrum fee pricing is most likely to yield the maximisation of consumer benefit from mobile data demand. As a consequence, taking proper account of these issues should lead Ofcom to the conclusion that the present proposed lump sum values of spectrum per MHz, at £23m for 900 MHz and £14m for 1800 MHz are too high.