Non-confidential

Application of spectrum liberalisation and trading to the mobile sector

Summary

Vodafone welcomes Ofcom's attempt to grapple with the thorny issues associated with spectrum liberalisation and trading within the mobile sector. However, Vodafone does not support Ofcom's proposed course of action which it notes is at glaring odds with Ofcom's principle to *"seek the least intrusive regulatory mechanisms to achieve its policy objectives"*.

Vodafone has a legitimate expectation that, when Ofcom exercises its spectrum management powers to propose such far-reaching measures it will base its decision on clear and compelling evidence and will demonstrate that there is an overriding public interest in any proposed course of action which entails such a substantial interference in the existing business interests of firms such as Vodafone. Ofcom has not demonstrated any such overwhelming public interest. Its conclusions are based on a hypothetical and fanciful version of the future which has no basis in evidence but to which it attaches weight.

However, even in the mythical world of the high demand scenario, Ofcom's cost benefit analysis is manifestly deficient. ✂ In addition, Ofcom's blithe assumption that the 900 MHz operators will know in advance whether or not to clear spectrum for their own re-farming is not only wrong but means that Ofcom ignores a critical additional element of risk for the 900 MHz operators: clearing five blocks if mobile broadband proves unpopular or only clearing three if it is a success. These observations alone should stop Ofcom in its tracks. However, Vodafone goes further and demonstrates that Ofcom has exaggerated the benefits of re-farming by at least a factor of 10 and ✂.

✂

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At the heart of conundrum lies the uncomfortable truth that there is not enough spectrum in the GSM 900 MHz spectrum ✂ Given this, if these advanced services do become popular, then operators should pursue a variety of methods to meet the demand. These will include: trading, leasing or sharing 900 MHz spectrum, national roaming on 900 MHz networks, network sharing, the use of substitute spectrum and the deployment of alternative technologies. It appears to Vodafone that the terms of its current licence under the Wireless Telegraphy Act,

taken together with Ofcom's policy towards spectrum liberalisation, spectrum usage rights and technology neutrality, already ensure that many of these options are possible. In addition, the UK has a long history of commercially negotiated roaming and MVNO arrangements and any competition issues relating to the sharing of networks will come before the OFT for examination shortly. At this stage, therefore, intervention of the type proposed by Ofcom is both wholly without basis and unnecessary.

Finally, quite apart from the many deficiencies in Ofcom's proposals noted above, it appears to Vodafone that it would be premature for Ofcom to proceed with its proposals at present: the judgment of the Competition Appeal Tribunal in the Floe case has given rise to substantial legal uncertainty as to the scope of Ofcom's spectrum management powers. Vodafone understands that this uncertainty is likely to be resolved in the second half of 2008.

If Ofcom were to await the outcome of the Floe appeal before proceeding, that would provide it with a much-needed breathing space to correct the many flaws in its analysis (and reconsult), to monitor the progress on network sharing, to discover whether operators wish to trade spectrum, to form a more informed view about whether (and when) the DDR spectrum will provide an adequate substitute for 900 MHz, and to proceed on a sound legal basis with any further consultation on a way forward.

Outline of Vodafone's response

Vodafone believes that Ofcom's approach to spectrum liberalisation and trading within the mobile sector rests on a number of premises which are either wrong or misconceived. Vodafone addresses each of these premises in the following four sections, together with the relevant Annexes):

1. Ofcom concludes that there is clear and decisive evidence that failure to intervene by Ofcom will result in a serious competition problem. Vodafone considers that there is no compelling evidence to support such a finding (Section 1).

2. Ofcom concludes that the cost of releasing 2 x 7.5 MHz of spectrum by the 900 MHz operators is clearly outweighed by the benefit of doing so. Vodafone demonstrates that this is not the case (Section 2).

3. Ofcom concludes that market mechanisms ─ e.g., trading between operators, national roaming, the purchase of substitute spectrum and network sharing ─ could not allow the non-900 MHz operators to enjoy the alleged benefits of re-farming. Vodafone takes issue with this conclusion, and explains how such mechanisms could be expected to work effectively (Section 3).

4. Ofcom appears to assume that it has a firm legal basis for embarking on this consultation at the present time. But there is substantial legal uncertainty as to the scope of Ofcom's spectrum management powers, until the Floe litigation is finally resolved (Section 4).

In section 5 Vodafone briefly summarises the conclusions from the previous sections and in section 6 we provide short answers to the specific questions posed by Ofcom.

Below, Vodafone briefly sets out its understanding of the current factual position relevant to spectrum re-farming. This provides the relevant counterfactual against which Ofcom must measure its various options.

Summary of the factual position

1. ✂.

2. ✂[1] As Enders Analysis – a respected firm of independent analysts – notes "*Other operators (e.g. O2) have pointed out that 2G spectrum is not spare and is currently used for 2G services, and the move to 3G has to be a lot more advanced before refarming becomes a practical option, but nonetheless having the option is a good thing.*"[2]).

3. All mobile network operators are deploying 3G at 2100 MHz and are required by the terms of their licence to cover 80% of the population by the end of 2007. The technical coverage thresholds set by Ofcom mean that this requirement equates to 'outdoor' coverage. ✂.

4. ✂.

5. At the present time the 1800 MHz operators are advantaged in the roll out of 3G by virtue of the fact that the frequency at which they operate is adjacent to 2100 MHz. This means that, rather than having to build new sites in order to achieve coverage, the 1800 MHz operators can simply, for the most part, upgrade existing sites to provide 3G capability. This makes for quicker and cheaper 3G rollout. In contrast, because Vodafone operates a network at 900 MHz it must build new 3G sites. ✂.

6. Four operators in the UK are currently engaged in discussions to share network infrastructure, via two proposed network sharing ventures.

7. Since the publication of Ofcom's proposals, in which the digital dividend spectrum is dismissed as a credible substitute for 900 MHz:

   (i) Ofcom has progressed in its thinking and now appears to contemplate the release of additional channels as part of the 'digital dividend';

   (ii) the World Radiocommunication Conference WRC-07 has identified part of the digital dividend spectrum (790-862MHz) for use by IMT (3G and beyond). This spectrum is already allocated to mobile in seventeen European countries (including UK), and this allocation will be extended throughout Europe by the time that analogue TV transmission is expected to cease. The European Commission has

[1] See Vodafone response to Ofcom's request for information relating to the liberalisation of 2G spectrum at 900 and 1800MHz ✂
[2] Enders Analysis: 'Ofcom wants it back' 27/09/2007

issued a Communication on "Reaping the benefits of the digital dividend in Europe: A common approach to the use of the spectrum released by the digital switchover"[3]; and

(iii) preparations for the US 700 MHz auctions in January 2008 continue, after which a continental market for UMTS and LTE technologies in these frequencies is expected to become available.

[3] COM(2007) 700; 13.11.2007

Section 1

There is no clear and decisive evidence that a failure to intervene by Ofcom will result in a serious competition problem

8. At the heart of Ofcom's analysis is a consideration of the costs and benefits of action (intervention to require the release of spectrum) and inaction (straight-forward implementation of the RSC Decision). Ofcom concludes that *"[i]f spectrum release were not mandated, there is a risk of significant weakening of competition in the UK mobile sector, with potentially far-reaching adverse effects for consumers of mobile services. If spectrum release is mandated, there is a risk of a one-off cost being imposed without corresponding benefits. Ofcom's analysis suggests that the impact of the former risk being realised would be much greater than the impact of the latter."*

9. There are three fundamental problems associated with this approach:

   (i) Ofcom constructs an 'extreme' high scenario of mobile broadband in order to evaluate the risk of inaction. This high scenario has no basis in any firm or compelling evidence and appears to be contrived to engender the very results that Ofcom comes to rely upon;

   (ii) Ofcom assertion that failure to act would significantly risk weakening competition is arrived at without evidence; and

   (iii) Ofcom concludes that, since the detriment associated with taking no action (in circumstances of high demand) outweighs the detriment to incumbent spectrum licensees of taking spectrum away from them (if that turns out to be unnecessary), action to guard against the former risk is preferable to action (i.e. no action) to guard against the latter risk. But Ofcom has no reason to attach greater weight to the former risk, unless it can show (which it has not) that it is materially more likely to result – i.e. that the high demand scenario on which it depends is genuinely likely to occur.

10. We tackle each of these errors in turn:

The 'high scenario' has no basis in evidence

11. Ofcom uses the methodology of a scenario analysis because it explicitly recognises that there is some uncertainty about the future demand for 3G services: *"Given there is some uncertainty about future level of interest in mobile broadband services, Ofcom in undertaking its analysis has considered a variety of scenarios to ensure that its proposed approach is appropriate, taking into account that uncertainty."* (paragraph 1.23)

12. Ofcom notes that it has *"considered a variety of scenarios"* however it appears that it is only the high and low scenarios that form the basis of its decision making. In correspondence with Vodafone Ofcom has explained that *"[t]he high and low demand for mobile broadband scenarios have been defined to aid our analysis of the costs and benefits for different policy options, the consultation document does not formally define, or rely upon, a core scenario for these purposes. The low and high demand scenarios have been defined such that they simplify the quantification task."* Ofcom refers to a medium scenario throughout the consultation but appears to place no weight upon it.[4]

13. Ofcom reviews the available evidence on the prospects for 3G and concludes that *"[i]t is Ofcom's belief that overall the evidence reviewed above suggests that it is likely that mobile broadband will become a more important and more widely used service for consumers. However we do recognise that not all the evidence supports this conclusion and that there is the possibility, albeit less likely in our opinion, that mobile broadband will not become any more important than it is today"*[5]. Ofcom also admits that *"there is limited evidence on the importance of quality for mobile broadband services"*[6] However it then deploys a deft sleight of hand. Ofcom's view that mobile broadband will become *"more important"* somehow morphs into an extreme[7] high demand scenario in which there is widespread take-up of mobile broadband services *and* the coverage of mobile broadband will be a key attribute when customers choose their supplier *and* that they will require coverage which mirrors that for 2G voice in the majority of the country.

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[4] *"We have not sought to quantify the costs and benefits associated with the medium scenario as this would be more complex and so difficult to do in a reliable way. We do not consider it necessary in order to make the policy choices required."* Correspondence from Ofcom 13 November 2007.
[5] Paragraph 5.25
[6] Paragraph 6.8
[7] Ofcom appears to concede that this is the case when it notes that the scenarios represent hypothetical cases that can *"**delimit** the potential differences of impact in quality"*. (our emphasis)

14. Ofcom simply cannot get from here to there. It presents no direct evidence to support this high demand scenario or analysis to explain the basis of its opinion. Ofcom's approach lacks transparency; the only information presented which directly attempts to measure consumers' interest for mobile broadband services, the market research carried out for the DDR, shows little current interest for such a service, with only 15% of the population likely to subscribe to a 2 Mbit/s service if it cost £5 a month. As Enders Analysis notes:

> *"There is very little justification given to the apparent desire of the operators for such a massive 3G build-out, with this central assumption supported by some vague comments that research suggests that UK consumers consider that high speed mobile broadband is "of value to society". Our research suggests that when asked the more direct question of whether they are interested in 3G services, 63% of UK mobile users are not at all interested with only 2% very interested (and these figures tend to get worse every year). Given this lack of demand, of which operators are all too aware, its is inconceivable that they would be planning such a dramatic investment, as Ofcom should know only too well, given that the GSM operators have already been objecting to the 3G licence requirement to build out to just 80% of the population."*

15. The same survey shows 31% of the population being likely to subscribe to a 2 Mbit/s service if it was free of charge and that interest in the service is highly dependent on price, with only 4% of the population likely to subscribe if the service cost £15 a month. In terms of the factors important to individuals for a mobile broadband service, the research showed that price was a far more important factor than coverage, with potential customers also giving "mobility" and download speed as more important factors. This information, which is not presented in the consultation document, appears to be consistent with the low demand scenario but inconsistent with the high demand scenario.

16. Ofcom therefore fails to substantiate its own view of the future and inexplicably disregards contrary evidence. This is an unsound basis for decision making.

Future competition problems amount to mere speculation

17. Ofcom compounds the inadequacy of its evidence base for the high scenario by indulging in a bout of speculative conjecturing about the competition problems that it asserts are **likely** to emerge if the current spectrum allocations stay undisturbed. The manifestation of these problems is alleged to be two-fold: either a) only two operators will roll out broadband

mobile services with the result that competition in this market will diminish and /or b) one or more operators will exit the market. There are a number of obvious deficiencies in the form of unsubstantiated but implicit assumptions in Ofcom's analysis. Ofcom, it appears, assumes that:

(i) There is a separate market for "mobile broadband" (see, for example, paragraph 6.21 which states "*In the medium demand scenario operators with 900 MHz may provide higher quality (than those without) due to their potential cost advantages, and as a result competitive intensity in providing mobile broadband services would fail.*") and operators are all required to compete in this market (or face the prospect of exit).

(ii) Five operators are required to ensure that the market is effectively competitive despite previously having found an absence of SMP in a four-player mobile market.

(iii) Spectrum alone determines a firm's ability to compete effectively in this putative market. Other factors such as brand, distribution, marketing etc. are assumed not to be determinative.

(iv) Vodafone and O2 would be dominant in the putative market and that Ofcom's available remedies would be insufficient to counteract the effects of that dominance.

(v) It will be profitable for operators to offer the quality of service required under the high demand scenario at 900 MHz.

(vi) It would be unprofitable to offer the quality of service required under the high demand scenario at 2100 MHz.

(vii) Operators could not pursue heterogeneous strategies and provide a different package of coverage and technology (e.g., Wi-Max or Femtocells).

(viii) Although not all customers demand mobile broadband services, an operator would exit the market rather than continue to provide other mobile services without mobile broadband (along the lines of many current MVNOs). (See Annex 6 for a critique of Ofcom's analysis of market exit).

18. Ofcom then attaches greater weight to the detriments associated with the failure to intervene in the high scenario (i.e., diminution of competition or inefficient rollout of 3G) through its novel use of the so-called 'precautionary principle'.

The misuse of the 'Precautionary Principle'

19. Ofcom uses a new decision rule in this consultation: the so-called 'precautionary principle'[8]. The rule appears to imply that, although there are risks to both action and inaction, because the costs associated with the latter are potentially greater than the former, requiring a release of spectrum is justified: "*Ofcom's analysis suggests that the impact of the former risk* [adverse consequences through not requiring a spectrum release] *being realised would be much greater than the impact of the latter".*

20. However, the magnitude of the relative risk is, of itself, not relevant. Ofcom must be saying something different. It must be suggesting that the 'high' demand scenario is more likely than the 'low' demand[9] or that the expected (i.e., weighted by probability) costs of inaction overshadow those of action. Ofcom however offers no reasoning to support this view. The furthest that it goes is to assert, in paragraph 6.23, that the high demand scenario is *"plausible".* However, by comparison, in the March 2007 Mobile Call Termination statement Ofcom describes a high voice and data traffic scenario as a *"very optimistic market outcome"*[10].

21. Ofcom's approach aptly demonstrates the emptiness of the precautionary principle[11] as applied here. Both action and inaction bring risks and therefore the principle can be invoked to justify both courses of action. Ofcom could just as easily have concluded that requiring a release of spectrum could risk imposing unnecessary costs on the 900 MHz

[8] See paragraphs 1.42, 8.31 and 14.15

[9] We presume that this is what is meant by the statement in paragraph 1.24 *"If, as Ofcom believes is relatively likely, consumers do value mobile broadband services and they become an important part of the mobile market, then the benefits from liberalisation of the 900 MHz and 1800 MHz spectrum are likely to be significant."* Although we mote that *"becoming an important part of the mobile market*" is not equivalent to the high demand scenario.

[10] *"High voice and data traffic: this scenario corresponds, for example**, to a very optimistic market outcome** in which aggressive mobile pricing drives high levels of fixed-mobile substitution for voice calls and emerging data services such as music and video downloads and location-based services prove to be highly popular."* (our emphasis) Paragraph 9.160

[11] See The Paralyzing Principle by Cass R. Sunstein University of Chicago*: "I have argued not that the Precautionary Principle leads in the wrong directions, but that if it is taken for all that it is worth, it leads in no direction at all. The reason is that risks of one kind or another are on all sides of regulatory choices, and it is therefore impossible, in most real-world cases, to avoid running afoul of the principle.*"

operators if the status quo is maintained (i.e., the low scenario) and therefore in order to avoid this eventuality it will not require the release of spectrum.

22. Moreover, the precautionary principle – which appears to be neutral between intervention and non-intervention – is arguably inconsistent with the honouring of Vodafone's legitimate expectations that Ofcom will intervene to revoke its spectrum licence only if there is compelling evidence that such revocation is necessary to achieve some overriding public interest objective. Vodafone's legitimate expectation is particularly weighty, given the substantial sums which Vodafone has invested in its continuing 2G business in reliance on its right to use its 900 MHz spectrum, subject only to the lawful revocation of those rights.

Summary

23. It is worth briefly summarising the steps in the logic used by Ofcom. The available evidence surveyed by Ofcom on the future demand for mobile broadband and the importance of quality to consumers is, at best, inconclusive. However, despite the distinct paucity of evidence, it is Ofcom's 'belief' that mobile broadband services will become *"more important"* and more widely used in the future. It is this assertion that forms the basis for the construction of the high scenario in which demand for mobile broadband is widespread and quality of coverage is critical. This high demand scenario permits Ofcom to calculate the risks of failing to require a redistribution of 900 MHz spectrum which it believes are greater than the one-off cost imposed on the 900 MHz operators (without corresponding benefits) if the demand for 3G reflects the low scenario. Ofcom then goes on to place greater weight, via the so-called precautionary principle, on the risk of inaction and concludes therefore that *"requiring partial spectrum release is most likely to meet Ofcom's objectives given the uncertainty regarding the future market development"* (paragraph 14.16).

24. This approach is, to put it mildly, not robust. Vodafone is entitled to expect that Ofcom will base such a significant proposed intervention on clear and decisive evidence. This is patently not the case. Ofcom arrives at its conclusions through unsubstantiated assumption. The evidence adduced by Ofcom is (as it admits) inconclusive and certainly does not underpin the high scenario. Ofcom appears to have confused the construction of a hypothetical scenario to *"delimit the potential impact of differences in quality on consumers"* with a state of affairs that is likely and to which it can attach weight in forming its conclusions. This approach is in stark contrast with that adopted in the recent Next Generation Access consultation where Ofcom states that *"[t]o be justified therefore,*

*evidence suggesting intervention would need to be **absolutely compelling** and to date it is simply insufficient to support such an interventionist approach."* (Next Generation Access consultation, paragraph 7.46 with our emphasis). It also contrasts with the cost benefit methodologies typically applied by Ofcom. For example, the market impact assessment of the BBC's High Definition television proposals published on 18 September 2007 where Ofcom states:

> "*This uncertainty about future HD take-up poses challenges for this MIA, as we need to assess the impact of the BBC service against the counterfactual of a scenario in which the BBC does not launch an HD channel – but in which other drivers towards HD (including HD production and HD broadcasting by other players) continue to develop. In the light of the significant degree of uncertainty over the future of HD take-up, we have considered three scenarios for this counterfactual – a central scenario, which forms the basis for the majority of our analysis, and higher and lower scenarios around the central case. This summary focuses on the central scenario, and we report sensitivity analysis in Section 4 of this document."*

25. In summary, Ofcom combination of the 'high' scenario and the precautionary principle provide a thoroughly unsound basis for policy making. Although, in fact, Vodafone's analysis in the next section and Annexes 1, 2, 3 and 4 demonstrates that the precautionary principle is unnecessary because action (in the form of a 2 x 7.5 MHz release) will always result in an unacceptably high cost to the 900 MHz operators whatever the state of demand.

Section 2

On a proper analysis Ofcom's cost benefit analysis does not support its proposed intervention

26. Vodafone contends that Ofcom's assessment of the costs and benefits associated with a spectrum release is deficient in at least four major respects:

(i) Ofcom has not recognised the inter-temporal nature of uncertainty. If a release of spectrum is required Ofcom must appreciate that the 900 MHz operators would need to make a prompt decision about how much spectrum to clear without certainty about what demand conditions will prevail. Failure to do this leads Ofcom to underestimate the risks associated with both the low and high scenarios.

(ii) Ofcom has ignored the fact that, in order to clear 900 MHz spectrum, Vodafone would need to invest significantly in 3G infrastructure at 2100 MHz ✂.

(iii) ✂

(iv) In any event Ofcom has miscalculated the costs and benefits associated with clearing 900 MHz spectrum and then using it for the provision of 3G data services. ✂.

Ofcom's analysis has an inadequate recognition of uncertainty

27. Even if Vodafone were to accept (which it does not – see paragraphs 42 to 54 below). Ofcom's quantification of the costs and benefits associated with spectrum release and re-farming it is still apparent that Ofcom has failed to grapple adequately with uncertainty. It has failed to appreciate that, faced with a requirement to release 2 x 7.5 MHz of spectrum in 2010, the 900 MHz operators would need to make decisions immediately about how much spectrum to clear i.e., without the luxury of waiting to see what the demand conditions will materialise. This is the case because the size of the clearance will determine the technology solution required – e.g., the use of SFH and / or the required investment in 3G infrastructure – and it can take at least ✂ to acquire and build a new site and so the magnitude of the acquisition programme must be determined in advance (see Annex 2 ✂). Ofcom just assumes this problem away *("Unlike the low mobile broadband scenario, here we assume that the existing 900MHz operators do wish to refarm 2 x 5.0 MHz each"* paragraph A9.247) and presumes that in the low scenario the 900 MHz operators do not re-

farm (i.e., the amount of cleared spectrum equals the amount of released spectrum) but in the high scenario they do (i.e., the operators clear an additional 2 x 5 MHz for mobile broadband rollout).

28. ✂ These are material risks that are completely ignored by Ofcom.

To clear spectrum Vodafone will need to improve its 3G voice network

29. Ofcom has also failed to recognise that the 900 MHz operators would have to invest in 2100 MHz infrastructure in order to migrate customers' voice usage from its 2G network i.e., to keep demand on that network flat. It is simply not the case that *"the bulk of the costs of the 3G strategy are those associated with subsidising the take up of 3G handsets"* (paragraph A9.264).

30. Ofcom assumes that a call made by a customer with a 3G capable handset will necessarily be made on 3G. This is mistaken. ✂. All 3G phones are 2G capable as well and where there is insufficient capacity or coverage for a call to be made on 3G, the call will be carried on 2G instead. ✂.

31. It follows therefore that it is not only largely pointless migrating customers to 3G capable handsets without investment in 3G cell site coverage/capacity to a similar level to that provided by 2G, but in fact it presents a considerable risk to 2G network quality. Calls will simply fall back to 2G once existing 3G capacity/coverage is breached; if this demand has not been allowed for in the planning of the 2G network then an increasing proportion of 2G calls will be dropped. The required easing of demand on the 2G network through 3G handset migration will just not happen. ✂.

32. A simple analysis can correct for the two deficiencies identified above (but still using Ofcom's data).

33. In 2008 (assuming this to be the date of Ofcom's decision) the 900 MHz operators will be required to decide whether to clear an additional 2 x 5 MHz for their own re-farming on top of the release of 2 x 7.5 MHz. This decision will clearly depend on the 900 MHz operators' views about the prospects for mobile broadband. The operators can either guess correctly about the future state of demand (green shading in the table below) or they can get it wrong (red shading). In the table below we detail the costs involved – using Ofcom's cost estimates – for all the relevant permutations.

✂.

- **Box 1**: ✂
- **Box 2**: ✂.
- **Box 3**: ✂.
- **Box 4**: ✂.
- We summarise these costs in the table below (further detail is provided in Table 55 in Annex 4):

✂

34. It seems that one of four things will happen under Ofcom's proposals[12]:

    (i) Under the low demand scenario the 900 MHz operators will each clear spectrum that will <u>not</u> be re-farmed ✂

    (ii) Under the high demand scenario the 900 MHz operators will either be required to build out their 3G voice networks at 2100 MHz before 2010 to migrate voice traffic from their 2G networks and clear spectrum with which to re-farm ✂:

    - according to Ofcom's analysis, there will be a reduction in competitive intensity because only three operators are in a position to roll out broadband services at 900 MHz. Ofcom estimates that the loss of total welfare to society from the consequent delaying of the introduction of an innovation into the mobile sector might be in the region of £250m to £1.5bn (see paragraph 11.26).; or
    - the 900 operators will be forced to build out their 3G data networks at 2100 MHz in order to compete with operators who are rolling out 3G services at 900 MHz at ✂.

35. It follows that Ofcom should not recommend the release of 2 x 7.5 MHz because either:

    (i) it is a complete waste of money; or

[12] It is arguable that operators would ever 'bet' on the high scenario to the extent that it assumes that traffic migrates to 3G (leaving traffic on the 2G network flat) because if this did not happen then the consequences for service quality would be disastrous.

(ii) it imposes an unacceptable high cost on the 900 MHz operators (Ofcom views costs in the range £0.8-1.4bn as an *"unacceptably high cost of release"* see paragraph A5.18); or

(iii) it would weaken competition in the UK mobile sector; or

(iv) it would require the 900 MHz operators to build out their 3G data networks (inefficiently) at 2100 MHz at ✂.

36. Vodafone's analysis shows that by recognising both the impact of uncertainty about future demand on the 900 MHz operators' decisions to clear spectrum and including the full cost of migration to 3G, Ofcom's proposals should fall at the first fence.

Ofcom's proposals will ✂

37. ✂.[13]

38. Clearing 2 x 12.5 MHz of spectrum would leave Vodafone with only 2 x 4.9 MHz of 900 MHz and 2 x 5.8 MHz of 1800 spectrum with which to run its 2G network. However, on the 900 MHz layer, ✂. Vodafone estimates that the costs associated with operating its network on only 2 x10 MHz of spectrum to be around ✂. .

39. The only option for Vodafone would be to migrate traffic to its 3G network. ✂. In Annex 3 Vodafone estimates that the investment in infrastructure and handset subsidies required to achieve this is of the order of ✂.

40. ✂.

41. ✂.

Ofcom has miscalculated the costs and benefits of clearing and using 900 MHz spectrum

[13] Ofcom cannot suggest that the 900 MHz operators could simply purchase some 1800 MHz spectrum because it argues in rejecting Option 1 that *"holding 900 MHz spectrum may provide a competitive advantage for incumbent licensees over their competitors who do not have access to that spectrum. In such circumstances it seems unlikely that holders of 900 MHz would sell spectrum to those who are currently not licensed to use it"*. By extension therefore if 900 MHz operators are put at a competitive disadvantage by being required to release spectrum and have need of some 1800 MHz spectrum to alleviate that disadvantage then why would the 1800 MHz operators sell? The impact of trading 1800 MHz on competitive intensity would not be *"low"* as Ofcom claims in paragraph 1.36. Therefore, by Ofcom's own analysis Vodafone will be unable to purchase 1800 MHz spectrum in order to ease its capacity problems. If Ofcom believes that the 900 MHz operators will not trade spectrum because of the potential increase in competitive intensity (see paragraph 8.31) then precisely analogous reasoning must apply to the 1800 MHz operators.

42. In Annex 1 Vodafone presents a comprehensive critique of Ofcom's assessment of the benefit of re-farming and the costs associated with clearing spectrum. In summary, Vodafone submits that:

(i) All calculations should be performed using a discount rate of 11.5%. The social benefits that Ofcom is evaluating will not be realized, if the private operators do not invest in the deployment of 900 MHz for the delivery of advanced services. Understanding the benefits to the operator is therefore critical, because it is only if these benefits are likely to be substantial that operators will invest in 3G using 900 MHz spectrum and hence society achieve the potential benefits. Therefore unless the cost benefit analysis concludes that there is a positive case using the commercial discount rate, there appears little reason to consider a cost benefit analysis using a social discount rate. All of Vodafone's calculations are quoted at 11.5%.

(ii) For coverage of up 80% of the population:

- Ofcom assumes that the proportion of 3G capable handsets within an operator's customer base is relatively low but builds a network which is sufficiently dense to support **all** customers on 3G.
- The calculations do not account for the reduced sensitivity of UMTS900 handsets. This increases the number of sites required.
- Ofcom uses incorrect in-building loss assumptions. Vodafone has previously supplied Ofcom with quantitative measurement data of in-building losses gathered from trials in Central London which show the differences in in-building losses for 2100 MHz versus 900 MHz is negligible. We understand that similar results have been reported in other Vodafone operating companies.
- Ofcom has ignored the fact that operators are currently deploying HSDPA. This will reduce the number of sites required because it handles data more efficiently and allows contended use of the service.
- Ofcom assumes that each operator uses 2 x 3G carriers at 900 MHz despite recommending a three block release i.e., one per operator. Correcting for this significantly increases the number of UMTS900

sites required in the simulation area by a factor of 30% in the medium scenario (Ofcom does not report estimates for the high or low scenarios).

- Ofcom's simulation area is unrepresentative of the 80% coverage area and the method used to extrapolate the results is contrived and should not be relied upon to support decisions of any kind.

- The level of voice traffic assumed in the simulation area is too high and when extrapolated across the remainder of the country is ✂ times that carried today by any of the 2G networks. In effect the simulation exercise is assuming that each network has 25 million customers. As a consequence Ofcom builds too many sites in the simulation area which are then scaled up across the rest of the country.

- Ofcom assumes that at 900 MHz or 1800 MHz an operator would choose to replace/supplement their 2100 MHz network with investment in a complete 900 MHz layer. This is unrealistic, in practice operators would, in all likelihood, seek to augment the coverage at 2100 MHz with that at 900 MHz.

- The build programme assumed for 3G coverage up to 80% (including in-building coverage) is optimistic, and internally inconsistent across scenarios.

(iii) For coverage beyond 80% of the population:

- The assumption that operators will supply mobile broadband services to 99% of the population appears to be wholly unsubstantiated by either evidence or economics.

- The build programme assumed for 3G coverage beyond 80% is profligate with 80% of sites built within two years of the spectrum award.

- The cell density calculations contain errors. When corrected the number of additional sites required at 2100 MHz versus 900 MHz is reduced ✂.

- Ofcom ignores the potential cost savings to 3G rollout at 2100 MHz through network sharing (see paragraphs 64 to 67 below).

43. Vodafone has attempted to correct for many of the deficiencies identified above. Our analysis shows that the per operator benefit to re-farming in the high scenario is, at most, £350m versus rollout at 2100 MHz without adjusting downwards to reflect savings in 3G rollout costs from network sharing (see Annex 3 for further details). Vodafone summarises its analysis in the table below:

Service adoption Level	Frequency band comparison (MHz)	Vodafone cost benefit (£bn)	Ofcom cost benefit (£bn)
Low	900 v 1800	0.1	1.2
	900 v 2100	0.0	1.4
Medium	900 v 1800	0.2	1.6
	900 v 2100	0.0	2.0
High	900 v 1800	0.4	2.6
	900 v 2100	0.3	4.3

Table 3: Cost advantage 900MHz vs. 2100MHz: Ofcom and Vodafone

44. Ofcom's calculation of the benefits from spectrum liberalisation and release assumes that all operators will be equally well placed to benefit from the liberalisation of the 900 MHz spectrum. It does not, however, specify the underlying reasoning that drives this assumption. If this assumption is incorrect, it would suggest that Ofcom has overstated the possible net benefits of spectrum liberalisation. Rather, the scale of benefits should reflect the ability of operators to achieve these benefits. If some potential users of the 900 MHz spectrum could not achieve the potential benefits, this should be taken into account in the assessment of the benefits of the proposed policy.

45. There are reasons why it may indeed be the case that not all operators will be able to attain the potential benefits and hence why Ofcom may have overstated the benefits from liberalisation. Evidence from the development of the UK mobile market over recent years suggests that not all operators are likely to be equally strong in all the elements that are required to be an effective competitor in the UK mobile market. If one operator is less able to achieve cost savings than others, this should be taken into account in the analysis. For

example, this could reflect differences in logistical, operational, managerial or technical capacity between firms.

46. In the on-going appeal of mobile termination rates it appears that ✂ believes that, under Ofcom's proposed charge controls, it will never ✂[14]. If this is the case then it is hard to imagine that ✂ will be in a position to benefit from re-farming. Ofcom should have considered this in its analysis and our per operator benefit figure above should be weighted for this effect.

47. In Annex 2 Vodafone presents a comprehensive critique of Ofcom's assessment of the cost of clearing 2 x 7.5 MHz and 2 x 12.5 MHz of 900 MHz. As a complement we estimate, in Annex 3, the cost of upgrading our 3G network (infrastructure and handsets) to migrate traffic from our 2G network in order to be able to clear ✂.

48. We summarise our view of the costs of 2G investment, 3G investment and handset migration in the table below (repeated from Table 57 in Annex 4).

[14] ✂

		2G investment £m	2G>3G handset migration £m	3G investment to 2010 £m	3G investment post 2010 £m	Total £m
Clear three	**Low demand**	✂	✂	✂	✂	✂
Clear three	**High demand**	✂	✂	✂	✂	✂
Clear five all 2G	**Low demand**	✂	✂	✂	✂	✂
Clear five, all 2G	**High demand**	✂	✂	✂	✂	✂
Clear five most on 3G	**Low demand**	✂	✂	✂	✂	✂
Clear five, most on 3G	**High demand**	✂	✂	✂	✂	✂

Table 4: Costs of Spectrum Clearance under High and Low Scenarios (Vodafone's numbers)

49. ✂.

50. Vodafone is now in a position to redo the table at paragraph 33 above showing the net cost of Ofcom's proposals using Vodafone's cost and benefit calculations for all permutations of spectrum clearance and demand.[15] (see Table 58 in Annex 4).

[15] For simplicity we assume that in the low scenario re-farming yields a benefit of zero and in the high scenario it produces a cost saving of £✂ per operator.

		State of demand after 2010	
		Low Demand	*High Demand*
Action by 900 MHz operators before 2010	**Clear and release 3 blocks**	-£✂	-£✂ [16]
	Clear 5 blocks and release 3 blocks	-£✂	-£✂ [17]

Table 5: Summary of the Net Cost of Spectrum Clearance (Vodafone's numbers)

51. Vodafone's analysis demonstrates that the costs to Vodafone and O2 associated with clearing spectrum far outweigh the benefits to the industry of rollout of mobile broadband at 900 MHz, whatever the demand conditions might be. Accordingly, Ofcom should not recommend Option C[18]. A similar result holds in the (arguably) more realistic medium scenario (see Annex 4).

52. Vodafone reaches this conclusion without considering further deficiencies in Ofcom's cost analysis namely the failure to account for the impact on competition of the 900 MHz operators of releasing either a 3 block or a 5 block of spectrum. Ofcom admits in paragraph 11.35 that releasing spectrum might result in *"some unavoidable transitional problems"* but declines to go further because it is difficult: *"[w]e cannot reliably quantify the risk of quality problems or the loss in consumer welfare that might result"*. Indeed, Ofcom then just assumes this inconvenient problem away *"[therefore] in estimating the costs of spectrum release we have assumed that the long term quality of 2G services is maintained"* (see also paragraph 10.36)

53. This is a serious deficiency in Ofcom's analysis. If Ofcom can attempt to quantify the welfare effects of a delay to innovation (see Ofcom's Annex 10) in a market that does not yet exist then it should attempt to quantify the impact of releasing spectrum on competition which does, especially as this market is, in Ofcom's own words *"very significant"* for the UK, generating economic benefits of £21.8bn with £19bn accruing to consumers.[19] Ofcom states that even a small reduction in the intensity of competition which led to just a 1% reduction in consumer benefits for ten years would represent a total loss to consumers of £1.5bn.[20] Therefore, any reduction of competition in this market must be considered very carefully indeed against the speculative and undoubtedly smaller impact of an imagined

[16] ✂.
[17] ✂.
[18] ✂.
[19] Paragraph 2.5.
[20] Paragraph 1.27.

reduction of competition in a "mobile broadband" market if and when it emerges. There are a number of dimensions of competition that will be adversely impacted by Ofcom's proposals and which it should have sought to quantify:

(i) **Cost of Supply**: Ofcom ignores the fact a release of spectrum will increase the marginal costs of supply of 2G services by the 900 MHz operators. This will diminish their ability to compete on price in that market and therefore diminish competition.

(ii) **Coverage**: In order to attempt to retain sufficient capacity on its network ✂ Vodafone (and presumably O2) would be required to build ✂. This effect has been recognised by Enders *"The networks will be sub-par for months, affecting the customers and the longer term reputations of the networks, and many people who chose Vodafone and O2 because it gave good coverage in their particular home or workplace will be disappointed to discover that this has changed. Major corporate clients may think twice about renewing their contracts given such uncertainty about future coverage. The cost of all this disruption is not included in the above figure [£200-770 million], or even estimated at all by Ofcom".*

(iii) ✂.

(iv) ✂.

(v) ✂.

(vi) ✂.

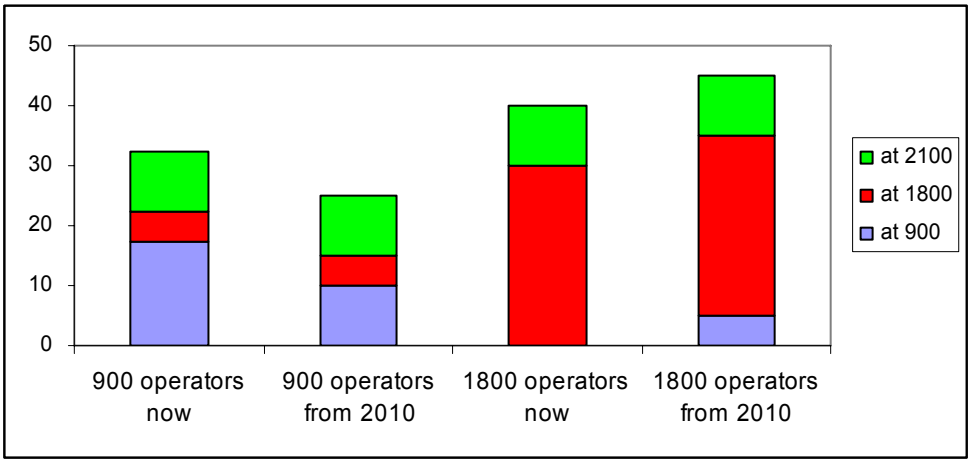
(vii) **New Services**: Ofcom has failed to consider the opportunity cost of devoting significant technical resource to overhauling Vodafone's network to cater for the release of ✂ spectrum.

(viii) **Future technologies**: Vodafone disagrees with Ofcom's view that a difference in holdings of 1800 MHz spectrum has no impact on competitive intensity (paragraphs 6.31 and 6.32). The European operators' position within the NGMN alliance is that LTE must be supported on the 900 MHz, 1800 MHz and 2.6 GHz bands for initial deployment (target for commercial availability is 2010). In 2010, under Ofcom's proposals, the 1800 operators will be able to re-farm part of their existing contiguous allocation of 2 x 30

MHz of 1800 MHz spectrum to deploy next generation mobile technologies. Vodafone however will be forced to use the 2.6GHz band (Ofcom dismisses the DDR as a candidate band for LTE) at much higher costs of network deployment. **Only the 1800 operators** would be in a position to allocate 10 MHz of spectrum to LTE; ✂.

If Ofcom is prepared to require the release of spectrum on the off-chance that 3G might prove popular and base its analysis over a 20 year time horizon then it should also tease out the longer term ramifications for competition of its proposals.

Relative Spectrum Holdings 900 vs. 1800 operators post 2010



54. ✂.

Section 3

Ofcom has prematurely and unjustifiably dismissed market mechanisms

Spectrum Trading

55. Ofcom's rejection of Option A is unfounded (see Annex 5 for a fuller explanation).

56. When using the framework of repeated games, the theoretical outcomes depend, amongst other things, on the pay-offs to the different parties, the timing of such pay-offs, and the relative weight different parties put to the pay-offs at different points in time. There is no evidence provided in Ofcom's exposition to support the position that repeated interactions between players are likely to lead to the sustainability of a tacitly collusive outcome, where both parties would not sell. By way of illustration, we provide at least one scenario in Annex 5 with what would seem to be for Vodafone more realistic assumptions about the pay-offs to the different parties, which would imply that a collusive outcome could not be sustained.

57. Ofcom seems to be arguing that the mere existence of a risk of a no trade outcome occurring under Option A (paragraph 8.31) makes it sufficient to reject that option. However, Ofcom has not provided any evidence that would allow an informed view of the materiality of this risk. The analysis of different potential outcomes using Ofcom's framework, and the experience of the development of the UK mobile sector provide no support to the assertion that a tacitly collusive outcome is anything more than a theoretical possibility. On the basis of the above assessment however, Ofcom rejects Option A.

58. It is worth noting that Ofcom does recognise that this option also has advantages, because it '*would be a relatively quick and simple approach to take. It would also have low costs as it would not impose new obligations…*' and ' *…it would be likely to bring about some efficiency benefits...*'. A more prudent approach therefore would be to 'test the market', which is now aware of the views that Ofcom espouses in this consultation (and its proposal to require the release of spectrum) and discover whether commercial arrangements between operators will achieve a wider distribution of 900 MHz spectrum.

59. There is sufficient time to pursue this approach because non-900 MHz operators suffer no competitive disadvantage as a consequence of the current distribution of 900 MHz spectrum ─ all operators deploy their 3G networks at the same frequency ─ and, even under Ofcom's

analysis of the requirements of the RSC Directive, it has until 2012 before it is required to take action.

60. Vodafone notes Ofcom's policy objective *"of widening access to 900 MHz spectrum (the purpose of which would be to protect against a reduction in competition and allow efficiency gains to be realised)"*[21]. However, there is only something to protect against if the 'high' scenario (or something like it) eventuates. Under the low scenario Option A is always preferable to Option C because presumably there would be no buyers of 900 MHz spectrum and no costs of release imposed upon the 900 MHz operators. Under the high scenario, then providing trading occurs, Option A trumps option C because *"if the timing of released and liberalisation were commercially determined between incumbents and acquirers of spectrum, this might in principle reflect the underlying costs and benefits better than if Ofcom tried to set the date"* (paragraph 11.100).

61. To repeat, a judicious approach therefore would seem to be to allow sufficient time to see whether there are willing buyers and sellers of 900 MHz spectrum. If there are no willing buyers then Ofcom need not worry. If there are willing buyers but no willing sellers then Ofcom will still have sufficient time to act before it butts up against its 2012 'back-stop' date[22].

National roaming

62. Ofcom's rejection of national roaming on UMTS 900 MHz is particularly weak. Although Ofcom sees some advantages in regulated national roaming it rejects this option for a number of reasons:

    (i) Reduced innovation and dynamic efficiency: Ofcom is afraid that a requirement to offer national roaming may *"slow down the rate at which the incumbents deploy 900 MHz infrastructure"* (paragraph 9.10). This is a theoretical possibility, however it requires the same kind of repeated game analysis that we criticise above. It is also possible that having a requirement to offer national roaming could **speed up** the rate at which the 900 MHz incumbents deploy their networks. This will happen if operators are competing for roaming business and wish to attract prospective roamers with the most extensive network and / or the act of completing a roaming

[21] Paragraph 1.67
[22] Paragraph 11.99

agreement improves the economics of rollout because operators expect greater revenue. Therefore the effects of roaming on rollout (and therefore dynamic efficiency) are far from unambiguous.

(ii) Ofcom is concerned that it might not get a roaming agreement 'right' if it were obliged to intervene. This is not a concern that Ofcom has expressed before. Indeed it was at pains to reassure H3G in its July 2004 publication *National roaming: A further consultation* that it could intervene quickly to determine an access agreement in the event of a dispute: it *"would be within Ofcom's discretion to impose an access-related condition on one or more 2G mobile operators in the future if it becomes proportionate to do so"* (paragraph 3.13). Ofcom goes on, in the same consultation, to reassure H3G that it could resolve any dispute, including a disagreement about the commercial terms of roaming, quickly: *"the ability of Ofcom to resolve disputes between 3 and any 2G mobile operator…no less speedily than it could if there was an access-related condition already in place; and the ability of Ofcom to impose an access-related condition in the future if needed to ensure that national roaming is available to 3, and to determine in a timely way the terms on which it will be supplied"* (paragraph 3.22).

(iii) Although the costs associated with UMTS 900 MHz may be more uncertain than 2G, Ofcom is used to, and perfectly capable of, forming a view about complex issues that are subject to a degree of uncertainty, for example, in the setting of 3G termination charges. Ofcom can never derive a perfect solution in the face of uncertainty but it can achieve an answer that is good enough to achieve an objective of allowing more than two operators the option of rolling out 3G services at 900 MHz. As Ofcom notes in its Outline Defence on Price Control Matters before the CAT its *"decisions in arriving at the final levels of price controls reflect a balanced judgement in the face of considerable uncertainty about many of the cost components in mobile call termination rates"* (paragraph 7).

63. Ofcom has conspicuously failed to compare the costs and benefits of Option B with those of Option C. Option B obviously trumps Option C in the low scenario and in the high scenario, under Ofcom's analysis, will avoid significant cost and disruption for the 900

MHz operators. Vodafone submits that the risks to dynamic efficiency from national roaming, if they exist, are insufficient to outweigh these costs.

Network sharing

64. The route so far to achieving lower costs of rollout for 3G for Vodafone is via a radio network share arrangement. Vodafone has said publicly that it expects that sharing its radio access network with Orange will reduce capital and operating costs by 20-30% across both its 2G and 3G networks. Similar arrangements are also being explored by H3G and T-Mobile where spokesmen from both H3G and T-Mobile are variously reported as claiming that network sharing will save both parties a *"significant"* amount of money and *"accelerate the rollout of the network to the target of 98% coverage"* and *"speed up the rollout of HSDPA"*[23].

65. Since it is the stated intention of at least four operators in the UK to enter into such network sharing arrangements it is curious that Ofcom is so dismissive of its implications for liberalisation in the mobile sector. In paragraph 8.59, without knowing the details of the proposed network sharing arrangements, Ofcom appears to pre-empt any analysis by the competent Competition Authority and conclude that *"there is a significant risk to competitive intensity and innovation"* from such arrangements. However, such an assessment cannot be made in a vacuum[24]. A more balanced approach would be to admit that this is a matter of uncertainty[25] (which may, of course be resolved during 2008) and that it may be possible that the relevant Competition Authority is comfortable that it is possible to structure network sharing arrangements so that there is no risk that operators, for example, will *"collaborate on network development and gain information about each other's costs and plans"*. Should this be the case then it will obviously significantly reduce Ofcom's analysis of the benefits to holding 900 MHz spectrum. Failure to recognise this is an obvious and serious deficiency in Ofcom's analysis.

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[23] See for example:
http://www.mobilenewscwp.co.uk/News/5104/tmobile_and_3s_network_share_deal.html,
http://www.mobiletoday.co.uk/content/16865.asp?men=2&sub=6,
http://www.theinquirer.net/en/inquirer/news/2007/09/20/3-uk-and-t-mobile-to-share-networks

[24] See the Court of First Instance's judgment of 2 May 2006 in Case T-328/03 O2(Germany) GmbH v. Commission where the Commission's decision in respect of O2 and T-Mobile's network sharing arrangement was overturned. The Court criticised the Commission's failure to properly consider the counterfactual without the agreement (paragraphs 74-79) and for not taking account of the fact that the agreement provided greater roaming rights over areas of low population density (paras 91-98).

[25] Ofcom recognises and claims to accommodate other forms of uncertainty e.g., future demand.

66. Moreover, given the uncertainty of demand that Ofcom itself acknowledges, network build-out may actually be greater if operators can share the risks and aggregate that demand. Ofcom notes that 900 MHz spectrum is best suited for rural low population coverage where demand is likely to be lowest and the business case for rolling out infrastructure most marginal. By aggregating demand an MNO with a roaming partner or network sharing partner may actually roll out infrastructure in places where neither partner would have the incentive to do so alone. Therefore, such an approach may lead to improved service competition for mobile broadband services in areas where there would otherwise be no competition at all. Ofcom cannot simply point to a potential reduction in innovation as a result of network sharing or regulated roaming and conclude that this results in an overall reduction of competition.

67. This point is particularly clear when one considers that all MNOs will already have their own 2100 MHz spectrum. If large-scale demand materialises in a particular area each operator can build their own infrastructure to accommodate that demand. If it does not, and the case is marginal, 900 MHz roaming may actually increase competition.

Digital Dividend Spectrum

68. Ofcom concludes that spectrum released as a result of the 'digital dividend' is not, or is not likely to be, an effective substitute for existing 900 MHz spectrum and that, accordingly, it should be disregarded when considering the competitive position of operators without 900 MHz frequencies (paragraph 6.27). Ofcom does not dispute that spectrum in the upper part of the UHF band (between 750 MHz and 862 MHz) is a good substitute in propagation terms. The spectrum is in fact superior to 900 MHz in this respect. But Ofcom maintains that there is uncertainty as to the availability of spectrum in Europe, the consequent availability of equipment and that release in 2012 would be too late to allow operators without 900 MHz frequencies to remain competitive in the market.

69. Whilst Vodafone agrees with Ofcom that 'digital dividend' spectrum is a good (in fact superior) substitute for 900 MHz spectrum, we disagree with the other aspects of Ofcom's reasoning.

Ofcom can defer a decision on 900 MHz to reduce uncertainty around the digital dividend spectrum

70. Ofcom itself recognises that its current proposals would be highly disruptive and costly to the existing 900 MHz operators such as Vodafone - although Vodafone shows in this submission that Ofcom still underestimates the impact. It would therefore be reasonable for

Ofcom to seek to defer imposing these costs on the operators until the question of whether or not the digital dividend spectrum is likely to be available as an effective substitute for 900 MHz can be resolved – since this could otherwise alleviate the costs.

71. A large element of this uncertainty is likely to be removed in Europe over the next 12 months – sufficient time to allow Ofcom to defer a decision until there is more certainty and at the same time meet its legal obligations in implementing the RSC decision. The World Radiocommunication Conference WRC-07 identified part of the digital dividend spectrum (790-862MHz) for use by IMT (3G and beyond). This spectrum is already allocated to mobile in seventeen European countries (including UK), and this allocation will be extended throughout Europe by the time that analogue TV transmission is expected to cease. Technical studies in CEPT have concluded that *"the harmonisation of a sub-band of the UHF band for mobile communication applications (i.e. including uplinks) is feasible from a technical, regulatory and administrative point of view"*[26]. The European Commission has issued a Communication on "Reaping the benefits of the digital dividend in Europe: A common approach to the use of the spectrum released by the digital switchover". This concludes that *"there is urgency to initiate the decision process on the common approach to the digital dividend"*.

72. Equipment is under development for both the 700MHz bands that will be auctioned in USA in January 2008 and the 900 MHz band in anticipation of liberalisation in EU countries following the repeal of the GSM Directive. These designs could be readily adapted for operation in the European digital dividend spectrum, and could become available within a couple of years after the European band plan is defined for the digital dividend spectrum (expected to be completed by CEPT during 2008, in response to a Mandate from the Commission).

73. It is therefore open to Ofcom to defer any conclusions on the 900 MHz spectrum until there is greater certainty on the digital dividend position. Vodafone recognises that this is uncertain at present, but we believe that important steps will be taken to reduce this uncertainty and that Ofcom can afford to wait without failing in its view of its legal duties. Given the costs which it is otherwise proposing to impose on Vodafone, we think this approach is the only proper one.

[26] CEPT Report B to ECC: Technical feasibility of harmonising a sub-band of Bands IV and V for fixed/mobile applications (including uplinks), minimising the impact on GE-06, July 2007.

2012 is not too late for the digital dividend spectrum to be an effective substitute for 900 MHz

74. As Vodafone notes in Annex 2 it will take considerably longer than 2 years to clear 2 x 7.5 MHz or 2 x 12.5 MHz of spectrum[27]. Ofcom itself believes that it is not required to implement the RSC Decision until 2012. In such circumstances, the fact that the digital dividend spectrum would not be capable of being exploited on a national basis until the completion of digital switchover in 2012 (which Vodafone accepts) should not exclude it from Ofcom's considerations.

75. Given Ofcom's current auction timetable for the digital dividend in 2009, and given plans for auctions in other Member States and in the US and Asia before or around the same time, it is reasonable for Ofcom to expect that UMTS700 or lTE700 equipment will be deployable by 2012 and thereby be an effective substitute for the UMTS900 equipment.[28]

Ofcom needs to consider the relationship between digital dividend and 900 MHz spectrum for long term competition

76. Ofcom's views on the prospects for future competition in the UK mobile market requires it to take a view on both digital dividend spectrum and 900 MHz spectrum and both UMTS and LTE. It has failed to do this in the consultative document.

77. Ofcom believes that possession of spectrum at lower frequencies confers a significant competitive advantage and that all firms in the UK market should hold a minimum of 5 MHz of such spectrum. Yet it is clear to Vodafone (a) that there is unlikely to be sufficient digital dividend spectrum available to allow more than 2 or at most 3 licences to be granted, thereby returning the UK rapidly to 'asymmetric' spectrum situation which Ofcom's current proposals are trying to move away from; and (b) that competition in the medium term which remains Ofcom's concern is also likely to depend upon the deployment of LTE, for which a minimum of 2 x 10 MHz is required (and for which Ofcom's current redistribution proposals are therefore ineffective).

78. Ofcom needs to consider digital dividend spectrum and 900 MHz licensing holistically if it is not otherwise to find that its objectives today are to be frustrated only a few years later. Ofcom's current proposals are also likely to dampen the development of 700 MHz

[27] ✂

[28] Telstra's Australia already runs a UMTS850 network. The services was launched commercially in October 2006 and uses Ericsson infrastructure with devices supplied by Samsung, Motorola and Nokia.

technologies for use in the digital dividend and demand for the spectrum, since in Ofcom's view all firms will be able to deploy UMTS900 instead (although Vodafone believes that both it and O2 will in fact be unable to do so).

79. The proper conclusion at this stage is that there is likely to be sufficient spectrum below 2 GHz (at either within the digital dividend or at 900 MHz) to support perhaps 3 or 4 LTE-based mobile competitors, but that a spectrum policy which aims to sustain 5 infrastructure based networks could simply starve all of them of sufficient spectrum to develop a broadband mobile market over the medium term. Ofcom cannot avoid the fact that the auctions of digital dividend spectrum are likely to return to the UK to the asymmetric spectrum allocations which Ofcom's current proposals attempt to avoid. The correct response to this is to revisit the current proposals, not to discount the digital dividend spectrum.

Section 4

There is considerable legal uncertainty regarding the need for Ofcom to take steps to permit re-farming

80. Mobile network operators in the UK already have the right to use any network equipment in their 900 MHz or 1800 MHz spectrum which is compliant with the RTTE Directive. This, in Ofcom's own words, is the effect of the Competition Appeals Tribunal's judgment in Floe Telecom Limited v. Ofcom (Case No. 1024/2/3/04) ("Floe"). If true, the entire basis of Ofcom's consultation is fatally flawed.

81. Ofcom states in the first page of its consultation:

> *"The focus of this consultation document is on the appropriate method for making the 900 MHz and 1800 MHz spectrum available for 3G in line with the RSC Decision."*[29]

82. The Consultation states further at paragraphs 3.18 to 3.20.

> *There are currently four licences in force which relate to the use of the 2G spectrum (the "2G licences")*
>
> *Each of these 2G licences contains provisions restricting the technology which may be used to transmit and receive over the relevant frequencies. These restrictions currently prevent the use of 3G technology.*
>
> *As set out above, the RSC Decision imposes an obligation on the UK to make the 2G spectrum available for use by 3G technologies Ofcom therefore considers that in order to fulfill the UK's obligations under the RSC Decision it must take active steps to change the existing licence position. The following section sets out the legal framework of Ofcom's discretion to change the existing licences, and the legal duties and objectives which set the limits of that discretion.*[30]

83. However, if the CAT's judgment in Floe is upheld, 900 MHz and 1800 MHz spectrum in the UK is already effectively liberalised in the hands of its current holders.[31] Thus, there is nothing that Ofcom needs to do to implement the RSC Decision and therefore, compliance

[29] Paragraph 1.5 of the Consultation
[30] Paragraphs 3.18 to 3.21 of the Consultation
[31] This is potentially subject to repeal of the GSM Directive which will, in any event, be repealed at European level without any need for action by Ofcom.

with the Decision cannot be used by Ofcom to justify its actions in any way. The CAT's Floe judgment states:

> "*For the Licence and the Exemption Regulations, taken together, to be compatible with the RTTE Directive (and later, if relevant, the Authorisation Directive) the Licence must be interpreted in such a way that Vodafone is authorized to provide, for commercial purposes, telecommunications services (and later electronic communications services) using the radio frequencies set out at paragraph 7 of Schedule 1 of the Licence for the purpose set out in paragraph 2 of the Licence. Vodafone's commercial exploitation of those frequencies pursuant to the Licence may, in principle, involve the use of* ***any User Station which has been authorized under the RTTE Directive****…"*[32] *(emphasis added)*

84. It is clear that Ofcom is both aware of this part of the judgment and what it means for its own spectrum management powers. Ofcom's own pleadings in front of the CAT and the Court of Appeal state:

> "✂"[33]

Even if Ofcom's appeal is successful, it cannot properly consult without taking account of the current uncertainty regarding the legal position

85. Clearly Ofcom disagrees with the CAT's findings in the Floe judgment, hence its appeal to the Court of Appeal to have that judgment overturned (which Vodafone understands is likely to be heard in March 2008). Not only would it be foolhardy for Ofcom to act before the Court of Appeal (and, if necessary, the House of Lords and/or the ECJ) have had the opportunity to clarify the situation, Ofcom's failure to publicly acknowledge this uncertainty has seriously undermined the transparency of the current Consultation. Despite being well aware of the far-reaching implications of the CAT's judgment in Floe to Ofcom's spectrum management powers, Ofcom has made no reference to it whatsoever in the over 300 pages of its Consultation.

[32] Floe Judgment at paragraph 146
[33] ✂.

86. The present situation is that Ofcom is bound by and must have due regard to the CAT's judgment; ✂.[34] Moreover, the CAT stated, ✂ that the Floe judgment is generally applicable to the exercise of all of Ofcom's duties.[35]

87. By effectively inviting all respondents to the Consultation to respond while ignoring the effect of the Floe judgment, Ofcom has fundamentally undermined the transparency of the Consultation. Vodafone has had access to Ofcom's pleadings in the Court of Appeal case and therefore is well aware of what Ofcom itself considers the implications of the CAT's Floe judgment is, but beyond T-Mobile, no other respondents are in such a privileged position. By failing to acknowledge the potential impact of the Floe judgment on the issues in question, Ofcom has failed in its duty to ensure that its regulatory activities are transparent to all interested parties.[36] Vodafone submits that this failure is so fundamental to the Consultation that it cannot simply be addressed by Ofcom's final statement.[37]

Limited liberalisation is required by the RSC Decision but mandatory spectrum release is not

88. Throughout the consultation, Ofcom conflates the obligation to enable UMTS equipment to be used in 900 MHz and 1800 MHz spectrum which is required by the RSC Decision and spectrum release. For instance Ofcom states:

> *"In order to fulfil the UK's obligations under the RSC Decision, as set out in the previous section, Ofcom must take active steps to change the existing licence position. The consultation options set out in this document may require Ofcom to vary and/or revoke the 2G licences, and possibly to grant new licences."*[38]

89. As noted above, if the Floe judgment is correct, it is not clear that Ofcom needs to do anything to ensure UK compliance with the RSC Decision, much less *"change the existing licence position."* Moreover, to be clear, the RSC Decision does not require spectrum release. In fact, its recitals state:

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[34] ✂
[35] ✂.
[36] S. 3(3)(a) Communications Act 2003 as well as Art. 5(2) of the Authorisation Directive
[37] The duty to provide a properly reasoned decision exists when general considerations of procedural fairness require it, including the extent of any interest affected by the decision and the need to demonstrate that issues have been properly addressed. In this case, such needs could hardly be greater given the enormous financial cost of Ofcom's proposals.
[38] Consultation at paragraph 4.5. See also paragraphs 14.13, 1.41, 2.3 and 2.5.

> *"the current use of GSM in the 900 MHz and 1800 MHz bands should remain protected in the whole Community as long as there is a reasonable demand for the service."*

90. Spectrum release as an integral part of liberalisation is necessary and proportionate only if, absent such a step, competition would be so badly distorted that this would be counter to Ofcom's duties. The RSC Decision puts it no higher than this:

> *"differences in national legacy situations could result in competitive distortions. The existing regulatory framework gives Member States the tools to deal with these problems in a proportionate, non-discriminatory and objective manner, subject to Community law including the Authorisation Directive and the Framework Directive."*

91. Rather than being compelled by the Decision to implement spectrum release, it is for Ofcom to make the case that such release is necessary in light of its statutory duties, most notably, to ensure the optimal use of spectrum and promote competition. It is for Ofcom to make the case based upon a proper analysis of the available evidence.

92. However, Ofcom's evidence base is exceedingly weak. In fact, it uses the uncertainty of future developments to justify spectrum release in relation to 900 MHz and to justify no release in relation to 1800 MHz.[39] This is insufficient. Absent an EU obligation, it is for Ofcom to give clear reasons why it has chosen to exercise its powers in a particular way and it has manifestly failed to do this.

Ofcom is breaching its primary duty to promote competition by risking severe disruption in the key markets of mobile voice and SMS services for speculative gains in a mobile broadband market

93. It is Ofcom's duty both under S. 3(1)(b) and under S. 4(3) of the Communications Act 2003 ("the Act") to promote the interests of consumers by promoting competition. It is clear that when considering how best to meet this duty Ofcom must give greater prominence to the larger market as that has the most significant and demonstrable impact upon consumers. Ofcom itself underlines the importance of the mobile sector in the UK in the Consultation.

[39] See paragraph 6.32 of the Consultation where Ofcom states "it is not certain that a wider distribution of 1800 MHz would lead to greater competitive intensity" while at paragraphs 6.21 and 6.23 Ofcom puts the case that asymmetric access to 900 MHz may lower competitive intensity no greater than "possible" or "plausible."

It states *"The mobile sector plays a vitally important role to citizens and consumers in the UK. It generated £16.5bn in retail and wholesale revenues in 2006 which amounted to just over a third of the total UK retail and wholesale telecoms industry revenue or 2006."*[40]

94. Ofcom's proposed mandatory spectrum release seriously threatens to distort competition in this primary market by constraining O2 and Vodafone's voice capacity and significantly increasing their costs of meeting growing demand for these services (see Section 2 above) Against these very clear and demonstrable effects on a large and vitally important sector, Ofcom places unproven beliefs that mobile broadband services will be highly sought by consumers who will place such a premium upon coverage and service quality that MNOs without 900 MHz spectrum will be unable to compete effectively and without regulatory redistribution and that MNO's without 900 MHz spectrum will be unable to get access to such spectrum upon commercial terms.

95. Ofcom correctly identifies that in exercising its duties (especially the duty to promote competition) it is principally concerned with ensuring that its actions do not reduce the current level of competition in the mobile market (which it has found "effectively competitive").[41] By failing to address the effect of its proposals upon MNOs' capacity to meet existing and growing demands for voice services, Ofcom has failed in this duty.

Ofcom's proposals do not give due regard to Vodafone's legitimate expectations regarding the proper exercise of its spectrum management powers

96. Vodafone notes Ofcom's statement that *"Ofcom considers no statements or representations were given at the time of that [3G] auction or at any other time which would give rise to a legitimate expectation in law in relation to liberalisation of the 2G licences."* Ofcom goes on to consider the legitimate expectations of existing 2G licence-holders and makes three points in support of its proposal to revoke 900 MHz spectrum in 2010:

    (i) the current 2G Licences contain provisions permitting revocation on one year's notice for reasons related to the management of the radio spectrum;

[40] Paragraph 5.3 of the Consultation.
[41] In paragraph 1.48, Ofcom describes the risk that "unless three blocks are released, the level of competitive intensity in the future might deteriorate from today" and describes the need to "safeguard the existing level of competition" in paragraphs 1.51, 1.48 and 1.68.

(ii) the licences also contain provisions allowing for variation or revocation "for the purpose of securing compliance with an international obligation of the UK;"

(iii) Ofcom acknowledges that in its SFR-IP it stated that it was likely a longer period than one year would be required for revocation "however, at the time the UK was not subject to any international obligation to make the 2G frequencies available for 3G use."[42]

97. However, these arguments fail to convince. In relation to (ii) it is clear from the discussion above that the RSC Decision does not require spectrum revocation and therefore Ofcom cannot point to its revocation plans as being *"for the purpose of securing compliance with an international obligation"*. Ofcom may decide that such revocation is desirable, but by no means may it say that it is required. Equally, nothing has changed in relation to (iii). If the Floe decision is upheld there is nothing further Ofcom needs to do to secure compliance with the RSC Decision. If not, then Ofcom itself considers it has up to five years to decide how to implement the Decision.

98. In relation to (i) even if the existing 2G licences do enable revocation upon one year's notice for spectrum management reasons, Vodafone and the other 2G MNOs have legitimate expectations (and have invested heavily in networks which they rely upon on this basis) that Ofcom's spectrum management powers would only be exercised with due regard to the reliance and investment that has been made, so that revocation will occur only where it is necessary to achieve some overriding public interest objective, and only on due and fair notice. In treating as equivalent the speculative gains available in "mobile broadband" with the very real and material burdens being placed upon Vodafone in the existing mobile market as a result of Ofcom's proposed actions, Ofcom has clearly failed to have due regard to these expectations. Vodafone submits that, had Ofcom paid due regard, it could not possibly have advanced its present proposals.

[42] Consultation at paragraphs 7.9 and 7.10.

Section 5

Conclusion

99. In conclusion Vodafone submits that Ofcom has based its analysis on a number of precarious foundations. In particular Ofcom has:

- Contrived, without evidence, the demand, quality and competitive conditions for a scenario in a market which does not yet exist. It then, after estimating the costs and benefits of action in the form of requiring a spectrum release in such circumstances, inappropriately places weight on this version of the future, via the precautionary principle, to justify its proposed course of action.
- Failed to appreciate that in order to migrate traffic from its 2G network Vodafone (and we presume O2) will require significant investment in 3G infrastructure to an extent that Ofcom's proposed intervention, even on its own criteria, cannot be justified.
- ✂.
- Manifestly miscalculated the costs and benefits of its proposals ✂.
- Prematurely rejected, on the basis of a theoretical model, the possibility that commercial transactions between operators will achieve its policy objectives. It does this despite the fact that this option is clearly superior to its preferred course of action if demand for 3G does not materialise.
- Prematurely concluded that the DDR will not provide an adequate substitute to 900 MHz spectrum and that network sharing will not deliver equivalent benefits to re-farming.
- Acted prematurely in making such a far-reaching decision which may (if Ofcom's appeal is unsuccessful) turn out to have proceeded on a false legal premise.

100. Vodafone submits that there is no pressing need for Ofcom to take action now in respect of the application of spectrum liberalisation and trading to the mobile sector and that, in any case, the action that it proposes cannot be justified on any reasonable grounds. Ofcom's own reading of the decision of the RSC's decision is that it does not have to implement that

decision until 2012. This means that Ofcom could allow sufficient time to correct the many inadequacies in its analysis (this will require a further consultation) and to discover whether: commercial transactions between operators establishes wider use of 900 MHz spectrum, network sharing between operators significantly reduces the benefit to 3G rollout at 900 MHz, the spectrum released by digital switchover will be a substitute for 900 MHz and there is any concrete evidence that anything akin to the high demand scenario is likely to materialise.

Section 6

Brief Answers to Ofcom's Specific Questions

Question 1.1 Do you have any other comments on this consultation document in addition to those made in response to the questions set out below?

Yes – see section 1 above

Question 3.1 Do you have any comments on Ofcom's interpretation of its obligations under the forthcoming RSC Decision?

See section 4 above. Vodafone notes that spectrum release is not required by the RSC Decision. Furthermore, Vodafone and the other 2G MNOs have legitimate expectations (and have invested heavily in networks which they rely upon on this basis) that Ofcom's spectrum management powers would only be exercised with due regard to the reliance and investment that has been made, so that revocation will occur only where it is necessary to achieve some overriding public interest objective, and only on due and fair notice. In treating as equivalent the speculative gains available in "mobile broadband" with the very real and material burdens being placed upon Vodafone in the existing mobile market as a result of Ofcom's proposed actions, Ofcom has clearly failed to have due regard to these expectations.

Question 5.1 Do you agree that the 900 MHz spectrum is likely to provide a cost advantage over higher frequencies for the provision of mobile broadband services? If so, do you believe that Ofcom's estimates of the size of that cost advantage are representative of what would realised in practice?

Vodafone's analysis indicates that the use of 900 MHz for mobile broadband provides a relatively small cost advantage versus rollout at 2100 MHz of around £350m per operator under the (fanciful) high scenario and no cost advantage in the medium and low scenarios (See Annex 1).

Question 5.2 Do you agree that the 1800 MHz spectrum is unlikely in practice to provide a cost advantage over higher frequencies for the provision of mobile broadband services?

Vodafone submits that neither 900 MHz nor 1800 MHz spectrum provides a significant advantage versus rollout at 2100 MHz

Question 6.1 Do you agree that if the existing distribution of the 900 MHz spectrum continued post liberalisation, this would be unlikely to promote competition for the provision of mobile broadband services?

No. The benefits to re-farming are relatively small and are only apparent in an 'extreme' version of the future. The magnitude of these benefits is insufficient to disrupt competition if they were to be only realised by the existing 900 MHz operators and, in any case, they can be achieved by the non-900 operators through commercial transactions between operators: trading, sharing, authorising the use of 900 MHz spectrum, national roaming, network sharing and the purchase of DDR spectrum which could all reduce the cost of rollout of mobile broadband.

Question 6.2 Do you agree that if the existing distribution of the 900 MHz spectrum continued post liberalisation, this would be unlikely to secure optimal use of the radio spectrum?

No. See section 4 of our main response. Vodafone believes that, post liberalisation, if holding 900 MHz does confer an advantage in the rollout of mobile broadband and operators wish to offer better and more extensive 3G services then commercial arrangements between operators will either achieve an optimal use of the radio spectrum or ensure than non-900 MHz operators can exploit the benefits of re-farming.

Question 6.3 Do you agree that if the existing distribution of the 1800 MHz spectrum continued post liberalisation, this would be likely to promote competition for the provision of mobile broadband services?

No. Ofcom's proposals will leave only the 1800 operators in a position to exploit LTE.

Question 6.4 Do you agree that if the existing distribution of the 1800 MHz spectrum continued post liberalisation, this would be likely to secure optimal use of the radio spectrum?

By Ofcom's own analysis the 1800 MHz operators would be unwilling to trade spectrum to their 900 MHz counterparts because, in doing so, they would halt the inevitable reduction in competitive intensity in the existing '2G market' following a forced release of spectrum.

Question 8.1 Do you agree with Ofcom's assessment of the merits of Option A (Liberalisation in the hands of the incumbents) for the implementation of the RSC Decision in respect of the 900 MHz spectrum?

No. Ofcom has dismissed spectrum trading on the basis of a theoretical model. Sufficient time exists to see whether the 900 MHz operators would trade spectrum given the alternative that they otherwise may be forced to release it.

Question 8.2 Do you agree with Ofcom's assessment of the merits of Option A (Liberalisation in the hands of the incumbents) for the implementation of the RSC Decision in respect of the 1800 MHz spectrum?

See our answer to question 6.4 above.

Question 9.1 Do you agree with Ofcom's assessment of the merits of Option B (Liberalisation in the hands of the incumbents subject to a roaming condition) for the implementation of the RSC Decision in respect of the 900 MHz spectrum?

No. There are good reasons to suggest that operators may compete to supply roaming services and that Ofcom is perfectly capable of regulating the terms and conditions therein should commercial negotiations break down.

Question 9.2 Do you agree with Ofcom's assessment of the merits of Option B (Liberalisation in the hands of the incumbents subject to a roaming condition) for the implementation of the RSC Decision in respect of the 1800 MHz spectrum?

Yes

Question 10.1 Do you agree that in principle some form of mandatory release of 900 MHz spectrum is appropriate in order to implement the RSC Decision?

No. Ofcom's analysis is deficient in many respects. Its conclusions rely on assuming (and attaching weight to) a fanciful version of the future for which no credible evidence exists. This is compounded by serious defects in Ofcom's cost benefit calculations.

Question 10.2 Do you agree that in principle some form of mandatory release of 1800 MHz spectrum is unlikely to be appropriate and that Option A is likely to be the most appropriate means to implement the RSC Decision in respect of the 1800 MHz spectrum?

Yes, although we note that Ofcom's view appears inconsistent with its views about when trading will or will not occur.

Question 11.1 Do you agree with Ofcom's assessment that the version of Option C in which there is the simultaneous release of three 2 x 5 MHz blocks of 900 MHz spectrum in 2010 is

likely to be the most appropriate means to implement the RSC Decision in respect of the 900 MHz spectrum?

No. Please see sections 1 to 4 above. A proper analysis of the costs and benefits associated with re-farming reveals that Ofcom's proposal imposes a net cost to the industry (and society) in both the low and high scenarios. Moreover, Ofcom has failed to grasp that its proposals would effectively prevent Vodafone (and we presume O2) from re-farming.

Question 12.1 Do you agree with Ofcom's proposal for the mechanism of release and the terms and condition for the released 900 MHz spectrum?

No, a spectrum release is not justified but, in any case, Vodafone would require until ✂ to release 2 x 7.5 MHz of spectrum (see Annex 2 ✂).

Ofcom sets out in Chapter 12 of the consultation its approach to the auctioning of the released spectrum, under Option C (Partial Mandatory Spectrum Release). Ofcom states that '… *we would not expect an auction to allocate efficiently released blocks of 900 MHz spectrum if incumbents were allowed to participate in the auction. This is because incumbent's valuation of the spectrum would include the benefits (to them) of holding that spectrum to reduce competition in the downstream market. This could result in incumbent's re-acquiring the spectrum even if it would be more efficient (and pro-competitive) if it were acquired by other operators*'. Although it is possible that 900 MHz operators will value the spectrum more than non-holders there does not appear to be a reason to expect *a priori* that this is more likely to be the case than not, or indeed that this outcome is relatively more likely. There are in fact a number of reasons for which such an outcome can not be considered likely:

- Under Ofcom's cost-benefit analysis, the (net) benefits of Option C are expected to be higher than Option A only under a scenario of high demand. Under a scenario of low demand, releasing of spectrum would provide no significant additional benefits to other operators, whilst leading to a real cost for incumbents. Mandatory release under the proposed Ofcom auction format would in such a case be expected to result in significant inefficiencies.

- As Vodafone has presented above, the estimated benefits from release for the acquirers of spectrum, when taking into account all relevant factors, are orders of magnitude lower than Ofcom has estimated, even in the high demand scenario. Ofcom has also failed to estimate accurately the costs to the existing holders of 900 MHz spectrum of

being forced to release up to 2 x 7.5MHz each. This implies, at best, significant uncertainty as to the overall net benefits of spectrum release on a high demand scenario, and at worst, that even in such a scenario mandatory spectrum release would be inefficient.

- It is far from clear that re-allocating the 900 MHz spectrum to other operators would result in achieving the benefits identified by Ofcom – there are a number of attributes and characteristics required by any acquirer of such spectrum to be able to achieve the benefits estimated by Ofcom, in addition to the spectrum itself. Ofcom did not seek to assess any of these other attributes, and the extent to which these are possessed by operators other than the incumbents.

- Ofcom has failed to provide any concrete evidence or quantitative assessment of the benefits to incumbents from the 'reduced competition in the downstream market' from not trading spectrum. This seems inconsistent with both the observed historic conduct of MNOs, having voluntarily provided access to successful MVNOs, and Ofcom's own assessment of the mobile market as effectively competitive.

It is therefore likely that the proposed auction design, which excludes incumbents from bidding, by ignoring these issues, could result in a very inefficient outcome; and a more inefficient outcome than for example an option where incumbents are allowed to trade, or incumbents are allowed to participate in the auction. Vodafone therefore believes that the auction design must be re-considered, to reflect at a minimum the very substantial uncertainties surrounding the potential costs and benefits from the re-farming of 900 MHz for 3G purposes. In the time available, and in view of the very significant issues that Vodafone has identified, it has not been able to consider the appropriate auction design in any great detail. Were Ofcom minded to proceed with its proposal however, Vodafone would expect another opportunity to consider the proposed auction design.

Question 12.2 Do you agree with Ofcom's proposal for the terms and conditions for the retained 900 MHz spectrum?

Yes

Question 13.1 Do you agree with Ofcom's assessment of the merits of Option D (Full Mandatory spectrum Release) for the implementation of the RSC Decision in respect of the 900 MHz spectrum?

Yes

Question 14.1 Do you agree with Ofcom's proposals for the implementation of the RSC Decision in relation to the 900 MHz spectrum?

No. Intervention of the type proposed by Ofcom is without basis and unnecessary.

Question 14.2 Do you agree with Ofcom's proposals for the implementation of the RSC Decision in relation to the 1800 MHz spectrum?

Yes

Question 15.1 Do you think that Ofcom should make the 900 and 1800 MHz spectrum available for systems other than GSM and UMTS? If so, for what systems, on what timescale and by what mechanism?

Vodafone favours technology neutral licences

Question 15.2: Do you believe that licences for the 900 and 1800 MHz spectrum should be made tradable? If so, on what timescale and should trading be subject to any competition restrictions ?

Yes in 2008.

Question 16.1 Do you believe that the licences for 2.1 GHz should be liberalised and if so on what timescale?

Yes in 2008.

Question 16.2 Do you believe that the licences for 2.1 GHz should be made tradable and if so on what timescale?

Yes in 2008.

Annexes

Annex 1 – Critique of the calculation of the benefits from refarming at different frequencies

Annex 2 - Critique of the cost of investment in 2G to clear spectrum: missing costs, cost underestimates, and failure to capture risks.

Annex 3 – Investment in 3G network and handsets to permit 2G spectrum clearance

Annex 4 – Summary of the overall costs and benefits of 2G spectrum clearance

Annex 5: A critique of Ofcom's rejection of Option A

Annex 6: Critique of Ofcom's welfare analysis

Vodafone UK

December 2007

Annex 1 – Critique of the calculation of the benefits from refarming at different frequencies

Summary

Ofcom has calculated that the benefit to each operator of rolling out a 3G network at 900 MHz rather than at 2100 MHz would be, at a minimum, £1.25bn and quotes a range of up to £4.25bn[1]. Vodafone does not believe that these estimates have been soundly, reasonably or realistically derived and thus is of the opinion that they cannot be used as a basis for decision making.

In general:

- There is an assumption that operators will always choose to build out their network to the maximum: there is no evaluation as to whether this is likely or financially viable. As a result, all benefit differentials 900 MHz vs. 2100 MHz are shown at their maximum possible value.
- All benefits are compiled and presented using a 3.5% cost of capital, when the correct rate to be used is at a minimum 11.5% as per paragraph 42.(i) in the main body of Vodafone's consultation response. Vodafone restates Ofcom's benefit calculations to 11.5% and then uses this rate for its workings.
- A series of errors overstates the differential in site requirements between frequencies.
- Ofcom is assuming a very early programme of site build that is at odds with its scenario assumptions used in the 2G refarming modelling of the rate of traffic transfer from 2G to 3G.
- Overall therefore, Vodafone believes that Ofcom has substantially overstated the site build/upgrade cost differentials that would emerge between the frequencies in real world circumstances. Vodafone estimates of the cost advantages of 900 MHz v 2100 MHz are shown in Table 1 below (values are summarised from Table 25 at the foot of this annex).

[1] £4bn for the high adoption scenario in the 80% coverage area, table 36, plus £0.25bn for the 80%-99% coverage area, table 22, all 900 MHz vs. 2100 MHz

Service adoption Level	Frequency band comparison (MHz)	Vodafone cost benefit (£bn)	Ofcom cost benefit (£bn)
Low	900 v 1800	0.1	1.2
	900 v 2100	0.0	1.4
Medium	900 v 1800	0.2	1.6
	900 v 2100	0.0	2.0
High	900 v 1800	0.4	2.6
	900 v 2100	0.3	4.3

Table 1: Cost advantage 900 MHz vs. 1800 MHz & 2100 MHz: Ofcom & Vodafone

In densely populated areas the approach Ofcom has used is not fit for purpose:

- In the simulation area used by Ofcom:
    - Ofcom overestimates the cost advantage of 900 MHz over 2100 MHz for 3G networks by making unrealistic traffic assumptions for its stylised networks. This leads to cell densities for its reference 10 km x 10 km zone, which are too high to apply in 2010 to the area containing 80% of the UK population: they are more reflective of the "endgame" position where there is 100% 3G penetration, although even in this scenario, the assumed voice traffic levels are still too high.
    - Ofcom's "core estimate" has been constructed in the annexes on the basis that **two** 3G carriers at 900 MHz will be available to each operator; however the body of the consultation makes it clear that only **one** carrier per operator is being considered. Ofcom's own sensitivity analysis shows the significant increase in sites required at 900 MHz when only one carrier is used.
    - Other methodological and practical errors exaggerate the difference between 900 MHz, 1800 MHz and 2100 MHz at a given traffic level in the simulation area.
- The simulation area that Ofcom has used is not representative of the 80% coverage area as it is more urban and traffic heavy. This means that Ofcom has been forced to apply a substantial but not substantiated "fudge factor", somewhat euphemistically described in the text as a 'planning efficiency factor', in scaling the simulation results to the coverage area as a whole. This factor has

been applied equally across all scenarios. Vodafone does not believe that this approach can give reliable and meaningful output.

- Ofcom then assumes a very rapid rate of site build that is not consistent with its 2G>3G migration scenarios, and would involve the construction of sites significantly before they are needed. The calculation also fails to take account of operator build in the period 2006-2010, in particular that arising from any 2G spectrum clearance.

In less densely populated areas:

- A6.5 states *"In less densely populated areas of the country, the primary aim of further investment is assumed to be increasing the extent of basic outdoor coverage. The costs associated with extending the population covered by 3G networks beyond 80% are examined in Annex 7."*

  In fact in Annex 7, Ofcom assumes a higher level of coverage than basic outdoor. Adjusting to assuming a more realistic level of 3G coverage reduces both the number of sites that are required at all frequencies and the cost advantages of 3G at 900 MHz considerably.

- Ofcom does not consider the presence or absence of any business case for a 2G operator to deploy 3G beyond 80% population coverage. In the low mobile broadband (voice only) scenario, there is no business case and therefore no cost advantage of 900 MHz over 2100 MHz. Only as demand for 3G specific services beyond the 80% coverage area rises does the need for 3G coverage commence: it is not axiomatic that cover to 99% will be established. Vodafone believes that a lower coverage percentage is more likely.

Introduction

This Annex critiques the calculations performed by Ofcom to assess the relative benefit of 900 MHz v 2100 MHz spectrum for 3G deployment. Primarily, it relates to Annexes 6, 7 and 8 of the consultation document.

Vodafone has examined Ofcom's scenarios and has built its own view of the possible benefits of 900 MHz vs. 2100 MHz spectrum. Neither Vodafone's nor Ofcom's estimates however are based on a detailed network planning exercise that would be required in the real world before commencing any build programme, that would reveal the real differences between the frequencies at a given traffic level.

Comments to Annex 8: Effects of frequency on provision of 3G services in densely populated areas

To form a view on the effects of frequency on provision of 3G for the 0~80% population coverage area, Ofcom's method consists of the following:

- A coverage planning exercise using the Atoll radio planning tool with assumed traffic profiles for a 10km x 10km area of north central London;
- An optimisation exercise using a commercial optimisation tool;
- An assumption that data traffic is carried by Release 99 bearers (i.e. no HSDPA);
- An arbitrary assumption that 80% population coverage requires 6,600 3G sites at 900 MHz;
- Extrapolating the results nationwide from the simulation area to calculate the corresponding cost of 3G deployments at different frequencies.

Vodafone does not believe that the results of this exercise are sufficiently robust to make decisions of any kind. The methodological and factual errors contained in Ofcom's analysis suggest that the size of the benefits calculated is likely to be substantially, if not grossly exaggerated.

Ofcom's scenarios

Ofcom has stated that its three scenarios which it has used for the simulation are of low, medium and high mobile broadband usage. In practice the simulation area scenarios in annex 8 make two un-stated assumptions, that all traffic is on 3G, and that all 3G traffic is on handsets that are capable of operating on UMTS900, UMTS1800 and UMTS2100. This however is in contradistinction to Ofcom's description of the scenarios elsewhere in the consultation document, and used for the calculation of the costs of 2G spectrum

clearance. Table 7 on page 100 summarises *"the assumptions made about the market outcome of liberalisation in the hands of the incumbents, in low and high demand scenarios, for the purpose of the costs and benefits analysis of mandatory spectrum release options."* Here it is made clear that the low scenario assumes that around 15% of mobile users have 3G handsets in 2010, and that 2G traffic levels are 20% above those of 2006. The high scenario assumes that around 35% of mobile users have 3G handsets in 2010, and that 2G traffic levels are similar to those of 2006. By interpolation, presumably therefore the medium broadband scenario would be that 25% of mobile users have handsets in 2010, and that 2G traffic levels are 10% above those of 2006.

In fact, however, the low, medium and high scenarios in the simulation area all use a constant number of customers per sq km per geotype: the only variation between the scenarios is in the proportion of users per sq km that are voice only, voice and medium-rate data, and voice and high-rate data users, as per Ofcom's Table 26. Thus, for example, in the low, medium and high scenarios there are always 7,500 users per sq km in the dense urban area, but in the low scenario 100% of them are voice only, in the medium generally 70% are voice only and 30% are medium rate data users and in the high scenario generally 50% are voice, 40% are medium rate users, and 10% are high rate users[2].

Although the mobile termination model is not useful for direct comparison since the geotype definitions it uses are not congruent with the spectrum simulation[3] it can be used as a point of reference. Taking an assumption of 15 million customers per operator, and using the termination model's traffic and area splits per geotype gives the comparison between users per square km shown in Table 2:

	Spectrum simulation	**Termination model**
Dense Urban	7,500	
Urban	4,500	5,860
Suburban	2,325	
Suburban 1		2,277
Suburban 2		182

Table 2: Comparison between users per square km per geotype

[2] At least in urban and suburban areas – a slightly different mix apparently applies in other geotypes but this may be a rounding issue.

[3] For example the termination model uses two suburban geotypes and one urban whereas the spectrum simulation uses one suburban and two urban.

This suggests that the two approaches are both from a consistent viewpoint, i.e. the user densities across all urban and all suburban environments are comparable, and thus represent the total number of customers of a mobile operator, rather than simply those users who are 3G capable in 2010. The comparison also hints that the number of users in the suburban geotype is too high in the spectrum simulation, a point returned to below. More realistically, the 7,500 total users per sq km in the dense urban area who will actually demand 3G service in 2010 must be scaled down by three factors, i.e. the % of 3G capable users, the % of these that have UMTS900 (or UMTS1800) capable handsets, and the % of the time such users are camped on 3G rather than 2G. This means that using Ofcom's scenarios of 15% and 35% penetration, the maximum number of UMTS900 users per dense urban sq km in 2010 can be no more than 1,125 in the low scenario, and 2,625 in the high scenario[4], but allowing for a less than complete penetration of UMTS 900 capable handsets, these values are still too high, probably by a factor of at least two.

Confusingly, when Ofcom was asked to supply the 3G handset penetration of the medium term scenario, the response was received: "*The high and low demand for mobile broadband scenarios have been defined to aid our analysis of the costs and benefits for different policy options, the consultation document does not formally define, or rely upon, a core scenario for these purposes. The low and high demand scenarios have been defined such that they simplify the quantification task. We have not sought to quantify the costs and benefits associated with the medium demand scenario as this would be more complex and so difficult to do in a reliable way. We do not consider it necessary in order to make the policy choices required. Consequently we have not needed to specify a particular level of 3G handset penetration associated with the medium demand scenario.*[5]"

Vodafone concludes that the 3G simulation area studies must therefore not be of potential demand in 2010, but of the long run demand once all customers have a 3G multi-band handset. Care must therefore be taken in interpreting the results: the sites and costs in Ofcom's tables 35 and 36 must thus not be the network that is required in 2010, but the network that may be required in due course once 100% penetration of 3G devices has been achieved. It is not clear to Vodafone whether Ofcom has formed a view of when this point will occur.

Ofcom's build programme would appear to assume that in 2008/09, each operator expecting to build in UMTS900, UMTS1800 or UMTS2100 will be able to decide as to whether the low, medium or high broadband demand scenario will apply, and will start building accordingly from 2009/10, i.e. immediately

[4] With presumably the medium adoption scenario somewhere at the mid-point of these scenarios.

[5] Email to Vodafone, 13th November 2007

after the auction and before the spectrum release actually occurs. Vodafone characterises this speculative building programme as the "if you build it they will come" approach. In the real world, an operator is unlikely to behave so cavalierly with its scarce resources. Vodafone suggests that all of the outcomes modelled by Ofcom involve substantially premature commitment of operator resources. There is no discussion in the consultation of when the 100% penetration point will be achieved and hence the timeframe in which Ofcom's cell builds actually become necessary to satisfy demand, under any of the three adoption scenarios.

Vodafone expects that investment in 3G cell site equipment will follow a more pragmatic pattern: the faster traffic increases, either/both through 3G voice penetration or data growth, the greater the rate of incremental capital investment. (The "we will build it as you need it" approach.) In reality, the growth of mobile broadband will be more of a "chicken and egg" situation: operators will only build capacity/coverage where it is economic, i.e. where profitable demand can be stimulated. This point is not considered in the consultation – there is an implicit assumption that operators will build to satisfy whatever level of data demand exists, irrespective of whether such traffic is profitable.

Vodafone does not believe that Ofcom's low scenario with 100% 3G penetration is realistic. One can instead conceive of a continuum of progressively reducing 3G cell size (and increasing site numbers) as 3G demand rises with handset penetration and the growth of mobile broadband. At one end is the 3G network that is required to ensure coverage inside the 80% area where there is only one concurrent 3G user. At this point, the "empty network", any differences between 900 MHz, 1800 MHz and 2100 MHz are minimised and cell sizes are maximised. As concurrent demand rises, both of voice and packet data, cell coverage shrinks, the number of cells required rises, and the relative differences between 900 MHz, 1800 MHz and 2100 MHz increase. Ofcom's low scenario is not relevant to 2010, rather it is representative of one possible 3G endgame outcome where there is 100% penetration of 3G but low adoption of packet data.

Critique of simulation results

Vodafone notes that there are errors in the simulation area methodology, relating to UMTS900 handset sensitivity, differential in-building losses, the treatment of packet data, and the number of 900 MHz carriers available for each operator. These are discussed in the sections below.

UMTS900 handset sensitivity

For densely populated areas, it is unclear if Ofcom's simulations have correctly accounted for the reduced sensitivity of UMTS900 handsets compared with UMTS1800 and UMTS2100 handsets. The UMTS900

handset sensitivity is relaxed by 3dB in the 3GGP specifications[6] to account for the narrower duplex spacing of the 900 MHz frequency bands. Ofcom is indicating that the 3G networks in their simulations are downlink limited. If differences in receiver sensitivity have been ignored, then there is a risk of material error in the calculation of the 900 MHz site numbers. (Ofcom's link budgets used for estimating site numbers for less densely populated areas do not account for differences in UMTS900 handset sensitivity.)

Since it is not clear whether Ofcom has taken account of this issue in the simulation, Vodafone is not suggesting a specific adjustment to the output: the point remains that if Ofcom has not compensated for this factor, then there is a likelihood that the number of sites required at 900 MHz to give service in the low, medium and high broadband scenarios have been understated.

In building losses assumptions

In respect of their analysis of in-building losses, Ofcom provides no supporting evidence to their qualitative arguments made in A8.15 and A8.37 regarding differences in building penetration losses with frequency.

Vodafone has previously supplied Ofcom with quantitative measurement data of in-building losses gathered from trials in Central London, which show the differences between in-building losses at 900 MHz and 2100 MHz are negligible[7]. Ofcom's own sensitivity analysis shows a reduction of the number of sites at 2100 MHz to 900 MHz of 35%. Vodafone notes that Ofcom's sensitivity analysis against what it describes as its central case includes a calculation of site requirements for 1800 MHz and 2100 MHz where "*in-building penetration loss does not change with frequency from its 900 MHz value.*"[8] Here at medium broadband adoption traffic levels, the sites required at the higher frequencies are given in table 38 as 11,300 at 1800 MHz and 12,200 at 2100 MHz, reducing the absolute site differentials with 900 MHz from 5,900 to 3,800 at 1800 MHz and from 10,300 to 4,700 at 2100 MHz. By reversing Ofcom's algorithm for converting simulation area results to the total 80% coverage area, it would appear that the simulation area results for lower penetration loss must have been 103 sites at 1800 MHz and 115 sites at 2100 MHz[9].

It is regrettable that Ofcom has not supplied equivalent results from their simulation at either the low or high broadband adoption traffic levels. Very crudely interpolating answers by applying the degree of difference

[6] 3GPP TS21.101 Release 6.

[7] Vodafone – Indoor losses, July 2007

[8] Paragraph A8.37

[9] To illustrate the sensitivity of the up-scaling calculation, had the results been 102, and 114 respectively, the required site numbers in the 80% area would have been 100 less at either frequency.

from the base scenario of low 900 MHz sites (37) to the medium 1800 MHz and 2100 MHz results with and without in-building penetration differentials gives the possible results shown in Table 3:

Sites in simulation area:		1800 MHz	2100 MHz
		No	No
A	Central estimate - Ofcom	133	194
B	Lower in building - Ofcom	103	115
C	Lowest 900 case - Ofcom	37	37
D	A-C	96	157
E	B-C	66	78
F	Discount E/D	69%	50%
G	Low adoption - Ofcom	90	139
H	Low adoption estimate , discounted for in-building adj ((G-C)*F)+C	73	88
I	High adoption	206	351
J	High adoption estimate , discounted for in-building adj ((I-C)*F)+C	153	193

Table 3: Implication of zero difference between in-building losses at 900 MHz and 2100 MHz.

Up-scaling the estimates derived in G and J for the simulation area gives possible site numbers for the 80% area under no in-building penetration differential, of 9,200 at 1800 MHz and 10,200 at 2100 MHz in the low broadband adoption case and 14,900 at 1800 MHz and 17,700 at 2100 MHz in the high broadband adoption case.

Ofcom's assumption of using release 99 bearers to carry mobile broadband data traffic

Vodafone believes that Ofcom's basic assumptions relating to the provision of mobile broadband are fundamentally incorrect. Ofcom has assumed in the simulation a guaranteed bit rate of 384kbps for the high-rate user or 144kbps for the medium-rate user for each and every indoor user of mobile broadband services using 3GPP release 99 bearers. This assumption is out of date as every UK operator is deploying, or has deployed HSDPA[10] technology as a basis for mobile broadband. HSDPA offers higher peak bit rates with a contended service for data users on a common data bearer with the following advantages:

- A single HSDPA bearer is applied to the downlink for all data users.
- More efficient multiplexing of data users on the HSDPA bearer compared to release 99 bearers.
- A substantially higher peak bit rate over a majority of the cell area with ~384kbps at cell edge. However, at peak periods, users contend for bandwidth so that data rate is not guaranteed.

With a contended service, user throughput is dependent on both the number of users and the profile of the actual data services concerned. However, by not guaranteeing throughput to the cell edge fewer sites would be necessary to offer high bit rate services. This is akin to fixed broadband networks, where user throughput is not guaranteed despite claims of 8Mbit/s broadband. The actual throughput is dependent on user contention ratios and the distance of the user from the local exchange.

This will have at least two impacts on Ofcom's simulation:

- To the extent that capacity is available in the HSPDA bearer at the point of demand, a "high" or "medium" rate user could in fact receive service at a higher rate than Ofcom's notional estimates, depending on distance from the cell site, up to the HSDPA bearer rate of 1.8mbps (or higher rates up to 14.4 mbps assuming 16 QAM HSDPA bearers). This means that, under these circumstances, the demands of each user would be satisfied in a shorter time and thus there would be fewer potential concurrent users in the busy hour. Vodafone asked Ofcom how many concurrent users the simulation was forecasting in the urban area and received the following response:
    - *"In medium adoption, each user adopting data services is assumed to use 10 Mbits (downlink) per day. 10%[11] of this is assumed to occur in the 'busy hour' so this means that 30% of the simulated users are active with 144 kbps for 10% x 10 x 10^6 / 144 x 10^3 = 6.94 seconds in each busy hour, which is the focus period for the simulation. Each user*

[10] High Speed Downlink Packet Access

[11] ✂.

additionally generates demand for voice services at 20mE in the busy hour or 0.020 x 60 x 60 = 72 seconds. These are the mean durations – the simulator actually generates calls and data demand randomly in each simulation cycle.

- *So given that users of classes 2 and 3 generate demand for data services, there are a total of 270 + 1080 = 1350 of these per square km in medium adoption. The average number of concurrent users of medium-rate data services will thus be 1350 x 6.94 / (60 x 60) = 2.6 per square km."*[12]

- However, if in fact these users are serviced through HSDPA at a higher rate, say 432kbps, or 3 times Ofcom's assumed 144kbps, then there will only be 0.9 concurrent users per sq km. This will presumably tend to reduce the number of sites required in the simulation area.

- Once the capacity of the HSDPA bearer is exhausted in a cell, it is not the case that any new data user is refused service: rather all concurrent users will be serviced at a slower rate. Whether this is a problem perceptible to the user depends on the nature of the service demanded, real-time vs. file transfer, streamed vs. download, device buffer size etc. This is a subjective rather than an objective matter. It is not axiomatic that network capacity will be provided so that all users can experience the maximum demanded speeds assumed by Ofcom at all times of the day; rather Vodafone expects that a pragmatic market led outcome to materialise which balances users' expectations in terms of speed, quality and cost, and network operators' investment costs and revenue rewards.

These points indicate that Ofcom's simulations under release 99 will overstate the number of sites that would actually be built in the real world in the medium and high broadband adoption scenarios, using HSDPA. Short of actually conducting a simulation using a modelling tool that uses HSDPA, Vodafone has no way of calculating the impact of this. For illustrative purposes, Vodafone has assumed that the medium scenario simulation overstates the site numbers required by 5%, and the high scenario by 15%.

The number of 900 MHz carriers

Vodafone notes that Ofcom's central estimate (table 38) for comparison is the medium adoption scenario with two carriers being available in each of 900 MHz, 1800 MHz and 2100 MHz. We cannot understand how this can be the central estimate when Ofcom is recommending the release of only 3 carriers at 900 MHz, i.e. one per operator. This to Vodafone highlights the disjointed nature of the consultation. There is a clear danger of inappropriate conclusions being drawn from the mismatch of scenarios and assumptions between

[12] Ofcom Answers to stakeholder questions relating to cost modelling, November 2007

the annexes and the body of the consultation and the consequent accidental misrepresentation of outcomes. Table 38 states that a reduction from two carriers to one carrier at 900 MHz in the medium scenario increases the number of sites required by 2,000, significantly reducing the differential to 1800 MHz and 2100 MHz. It is regrettable given that the use of one carrier at 900 MHz licensed to three or five different operators is Ofcom's currently preferred outcome that it has not chosen to model this at either the low or high adoption scenarios, or present this as the central estimate. (In fact Ofcom has strangely not presented any sensitivity analyses at either the low or high adoption scenarios.) It is clear however that in both high and low scenarios the reported site and hence cost differential would be reduced, and hence the benefits of each of the scenarios will be overstated in table 36.

Vodafone has attempted a crude estimation of the impact of switching to one 900 MHz carrier only in the low and high demand scenarios. The 9,500 sites from one 900 MHz carrier quoted by Ofcom in table 38 for the 80% area in the medium scenario is equivalent to 78 sites in the simulation area, compared to 49 sites under two carriers. This is a significant uplift of 59%. A similar uplift in the high scenario would give not 62 but 99 sites in the simulation area, or 11,000 in the 80% area, compared with the 8,400 sites with two carriers. This increase of 2,600 sites does not seem to be out of proportion with the 2,000 sites under the medium scenario. For the low adoption scenario, a similar uplift would take sites in the simulation area from 37 to 59, or from 6,600 to 8,200 in the 80% coverage area, an increase of 1,600.

Extrapolating the simulation area results to the total 80% coverage area

Having derived a set of results in the simulation area, Ofcom has then up-scaled these numbers to the whole 80% coverage area. The method of conversion is not clear from the consultation text, so Vodafone obtained clarification from Ofcom of the method used. (The description of the algorithm used subsequently supplied by Ofcom is not precisely correct, but Vodafone was able to disentangle it to produce a calculation that derives Ofcom's results).

Fundamentally the up-scaling calculation is grossly inadequate in several respects. The approach Ofcom has employed is as follows:

- Identify the "base" 80% configuration i.e. the number of sites required to give "adequate service levels" i.e. indoor and outdoor coverage as appropriate at UMTS900 in the low adoption scenario. This is given as 6,600 sites.

- Match this to the number found in the simulation area to do the same = 37 sites.

- Identify the increment in sites required in the simulation area under an alternative scenario. For example, the simulation states that at 2100 MHz in the medium adoption scenario, 194 sites are required, an increment of 157 sites.

- Reduce this increment by a factor, described in A8.29 as a "planning efficiency of 40% to account for the practical placement of sites in population centres and to account for terrain variations". In fact the calculation multiplies by 40%, so strictly speaking the reduction is 60%. 157 times 40% gives 62.8 sites as the increment.

- Divide this reduced increment by the base number of sites, i.e. 37 – this gives a factor of 1.697.

- Multiply this by the base number of sites at 80%, i.e. 6,600 times 1.697 = 11,202 extra sites.

- Add this to the base number of sites, 6,600, to get the total number of sites required under this scenario, i.e. 17,802 sites, rounded by Ofcom to 17,800.

It is possible to criticise this crude desktop substitute for a real planning exercise across the whole 80% area in a number of ways:

1. The origin of the base level of 6,600 sites is obscure. Ofcom states in A8.28 that it is *"representative of the number of sites currently deployed to deliver 3G services at 2100 MHz, based on Ofcom's understanding of information supplied by operators."* The relevance of this number, which even if representative, concerns outdoor coverage at 2100 MHz to indoor and outdoor coverage at 900 MHz is not clear to Vodafone. It is not obvious what work Ofcom has done to establish that 6,600 sites is the correct number to use in these rather different circumstances. If this number is incorrect then everything else in the calculation fails. Reducing it by say 10% reduces the site differentials by the same percentage: the impact appears to be linear in both directions, subject to rounding differences.

2. The up-scaling is incredibly sensitive to the base simulation result of 37. Increasing it by one reduces the number of sites in the scenario above by 400, from 17,800 to 17,400.

3. Any up-scaling to the 80% area given by Ofcom as 31,345sq km (in Table 17) from such a small area, 100sq km - the ratio between the two is obviously 313:1 – relies on an assumption that the simulation area is representative of the total. Ofcom, on request from

Vodafone, has supplied a breakdown of the simulation area by geotype, as summarised in Table 4:

Geotype	% of area
1 water	3.4%
2 open	6.0%
3 forest	4.8%
4 suburban	53.6%
5 open in urban	14.2%
6 urban	16.6%
7 dense urban	1.5%

Table 4: Percentage area by geotype within 100sq km reference area.

Categories 4, 6 and 7, the more densely populated geotypes collectively correspond to 71.7% of the simulation area. However Ofcom in table 17 split the 80% area into 10,203 sq km of "densely populated area" i.e. 32.5% and 21,136 sq km of "less densely populated area", i.e. 67.5%: this distribution would seem to be the inverse of that in the simulation area.

Other indicators also suggest that the simulation area is not representative of the 80% area. Using the above geotype breakdown of the simulation area, and the users per sq km in each of the 7 geotypes from table 28 can give the total number of users assumed by Ofcom in the simulation area, calculated by Vodafone as 210,765. As each user has an assumed voice demand of 20mE in the busy hour, this gives a BH traffic total of 4,215E. Assuming 15 million total network users, total traffic will be 300,000E[13], and assuming 10kE of this is outside the 80% area, then the ratio of traffic in the simulation area to the total in the 80% area is 1:69. Relating this to the area ratio suggests that traffic in the simulation area is 2.6 times denser than in the 80% area as a whole.

Running several other calculations reveals the ratios shown in Table 5 between the simulation area and the 80% area:

[13] ✂

Calculation	Ratio
Total area	1:313
Traffic	1:69
Traffic density	1:2.6
No of sites (base case)	1:178
Proportion less densely populated	1:2.4
Area: traffic	1:4.5

Table 5: Comparison of simulation area with 80% population area

This demonstrates that the simulation area is not representative of the 80% area, being substantially more urban, with a much higher average traffic load per sq km. It follows therefore that it will also have a higher proportion of indoor demand than the 80% area.

4. Given this, it cannot be safely held that the relationship between the scenarios observed in the simulation area will be maintained on a constant uplift basis across the whole of the 80% area for all scenarios. Indeed there would seem to be good reasons why it will not. The output of table 34 in the simulation area shows for each frequency that as the density of traffic rises, the number of sites required increases. So at 900 MHz the low scenario requires 37 sites, but at the medium broadband adoption level 90, and at the high 139, uplifts of 133% and 275% respectively. The driver for this is the cell breathing impact – but the effect of this will be much more pronounced in urban areas, where the density of traffic is greater, and where a much higher proportion of the traffic is forecast as indoor. Vodafone expects that the vast bulk of the increase between these scenarios will be incurred in cells serving urban geotypes: as is established above, these are overrepresented in the simulation area. It follows therefore that a simulation area that was one-third dense and two-thirds less dense will have a much less substantial proportionate uplift between scenarios than the simulation area used by Ofcom, being two-thirds dense and one-third less dense. Further the degree of overstatement will not be linear – at higher traffic levels and higher frequencies it can be expected to be magnified.

5. Ofcom has attempted to fudge a way round the obstacle of the non-representative nature of the simulation area via the “planning efficiency factor”. It is not clear that the value of 40%

(or 60% reduction) is any more than arbitrary. In fact the literal meaning ascribed to it by Ofcom, "*to account for practical placement and terrain variations*" would seem to suggest that it should have a value of greater than 1. Vodafone's interpretation of it is "to eliminate the misleading increment arising from the fact that the simulation area is very different from the 80% area as a whole." Looked at in this light, the fudge factor of 40% implies a reciprocal scaling differential of 1:2.5, not dissimilar to some of the values in the table above. Without this adjustment being employed, ludicrously large number of cell sites at higher frequencies would be output by the calculation. To choose a simulation area that is not representative of the whole and then adjust by a factor of 2.5 is no way to derive robust results however. Outcomes are very sensitive to its value – in the calculation of the 2100 MHz medium adoption scenario, changing the 40% to 30% reduces the resulting total of sites by 2,800 from 17,800 to 15,000. Substituting this value into Ofcom's calculation of costs reduces the total savings at 3.5% by £600m! Given Vodafone's conclusion that any adjustment to compensate for non-congruence should vary with volume and frequency, there is a strong suggestion that all of the benefit calculations between 900 MHz and 2100 MHz are exaggerated.

Vodafone has calculated the implied traffic demand for voice in the 80% area, in Ofcom's scenarios, using a geotype split of traffic, in order to look again at the discontinuity between the simulation area and the 80% area. It is possible, using Ofcom's assumptions, to build up a picture of offered traffic in the two areas. The traffic profiles for Ofcom's 10km x 10km reference area are defined in Annex 8, Tables 26-30. The corresponding traffic densities per unit area for the different clutter types are summarised in Table 6:

Class	Voice users/km^2	Erlangs/km^2
water	5	0.1
open	5	0.1
forest	5	0.1
suburban	2,326	46.52
open in urban	5	0.1
urban	4,500	90
dense urban	7,500	150

Table 6: traffic densities per km^2 – voice demand – all scenarios

Vodafone's estimate of the clutter distributions for the 31,345 km^2 estimated by Ofcom to encompass 80% of the UK population is summarised in Table 7. "Water" and "open in urban" geotypes defined by Ofcom are included in "Open" in this table:

Class	Area / km^2	Area / %
Dense urban	161.81	0.52
Urban	207.88	0.66
Suburban	9,901.99	31.59
Forest	123.65	0.39
Open	20,949.67	66.84
TOTAL	**31,345.00**	**100.00**

Table 7: Estimated UK clutter distributions for 31,345 km^2 area.

Extrapolating the user densities out to the 80% population area, Vodafone calculates the offered voice traffic to Ofcom's stylised networks and implied number of total users in the 80% area to be as defined in Table 8.

Class	km^2	Voice Traffic (Erlangs)	Users/km^2	Users per geotype
forest	123.65	✂	6	742
suburban	9,901.99	✂	2,325	23,022,150
open	20,949.67	✂	6	125,700
urban	207.88	✂	4,500	935,460
dense urban	161.81	✂	7,500	1,231,575
TOTAL	**31,345.00**	**>500kE**		**25,315,627**

Table 8: Offered traffic in low broadband scenario

This method of up-scaling the traffic suggests that the offered busy hour voice traffic in the 80% area is greater than 500kE, rather than the 300kE based on a simple number of users, as above. But since the calculated number of users per operator in the 80% area is in excess of 25 million rather than the approximately 15 million in the real world it would imply that Ofcom's numbers of users per sq km are on the high side, particularly in the suburban area. This suggests that there is too much voice traffic being forecast in the simulation area, even given the fact that it is not representative of the 80% area. This further brings into question the value of the simulation outputs, and the up-scaling calculation.

A further issue is that Vodafone believes that Ofcom has adopted for its definition of the area of the UK covering 80% population (31,345 km2[14]) as the area of the census regions containing 80% of the UK population. Vodafone believes that the actual area in which 80% of the UK population is contained is rather less. This further clouds the issue of up-scaling.

Vodafone therefore submits that the up-scaling exercise cannot be relied on to produce robust results. Ofcom's outputs exaggerate the impact of the difference in required site numbers at varying frequencies in the 80% coverage area. Vodafone believes that Ofcom should have conducted its analysis using more appropriate assumptions and a more stringent engineering approach for its derivation of site numbers. In the time available for Vodafone to respond to this consultation, it has not been possible for Vodafone to perform such an extensive simulation activity. However, Vodafone's methodology would be as follows:

1. Define the total busy hour traffic offered to the network (voice and data). One scenario chosen should be of real current network traffic.

2. Distribute the offered traffic over the total area of the network weighted appropriately to different population distributions, e.g., this could be urban, suburban, rural geotypes etc. Ideally this would be based on actual traffic distributions from a real network, e.g. 2G.

3. Calculate the average traffic density per distribution type.

4. Perform simulations for reference areas of each distribution type, assuming the average traffic density derived from 3 above, to estimate the average 2G and 3G site densities required per distribution type.

5. Calculate the total number of 2G and 3G sites required by multiplying the average site densities by the total area of each distribution.

[14] Annex 7, Table 19

6. Calibrate this calculation by checking that the model predicts reality, i.e. that the total 2G site numbers generated by this method using real traffic levels correlates with actual 2G site numbers, to ensure there are no errors in the assumptions. Correct assumptions as necessary.

7. Apply any corrections to assumptions to 3G calculations to estimate the number of required 3G sites.

Scenario outcomes – site numbers

Ofcom has supplied in its table 35 the results of the simulation study and the up-scaling calculation to give a set of site numbers required at each frequency: it also supplies in table 38 the results of a few sensitivity analyses (individual, not combined) that it has conducted only at the medium adoption scenario.

It is worth reproducing table 35's results here (in Table 9).

Broadband scenario	Sites required			vs. 900 MHz result	
	900 MHz	1800 MHz	2100 MHz	1800 MHz	2100 MHz
Low adoption	6,600	10,400	13,900	3,800	7,300
Medium adoption	7,500	13,400	17,900	5,900	10,400
High adoption	8,400	18,700	29,000	10,300	20,600

Table 9: Reproduction of Ofcom Table 35 – site requirement at varying frequencies and traffic levels

Vodafone has suggested above several necessary amendments to these numbers:

- Adjust for only one carrier at 900 MHz.
- Adjust 1800 MHz and 2100 MHz to eliminate the incorrect higher in-building penetration loss than 900 MHz.
- Adjust for the differences arising from the adoption of HSDPA.
- Consider the sensitivity of errors in the up-scaling calculation.

Table 10, Table 11 and Table 12 consider the results of these adjustments – Vodafone has come up with a core outcome in each demand scenario and then considered the implications of an up-scaling error of plus or minus 20% to give some view of the range of possible outcomes.

Low adoption	Sites required			vs. 900 MHz result	
	900 MHz	1800 MHz	2100 MHz	1800 MHz	2100 MHz
As Ofcom	6,600	10,400	13,900	3,800	7,300
900 MHz 1 carrier - VF	8,200	10,400	13,900	2,200	5,700
Inbuilding equality - VF	8,200	9,200	10,200	1,000	2,000
HSDPA adj - n/a	n/a	n/a	n/a	-	-
Possible outcome	8,200	9,200	10,200	1,000	2,000
Outcome - 20%	6,600	7,400	8,200	800	1,600
Outcome +20%	9,800	11,000	12,200	1,200	2,400

Table 10: Adjustments for low adoption scenario

Medium adoption	Sites required			vs. 900 MHz result	
	900 MHz	1800 MHz	2100 MHz	1800 MHz	2100 MHz
As Ofcom	7,500	13,400	17,900	5,900	10,400
900 MHz 1 carrier - Ofcom	9,500	13,400	17,900	3,900	8,400
Inbuilding equality - Ofcom	9,500	11,300	12,200	1,800	2,700
HSDPA adj - say 5%	-500	-600	-600	-	-
Possible outcome	9,000	10,700	11,600	1,700	2,600
Outcome - 20%	7,200	8,600	9,300	1,400	2,100
Outcome +20%	10,800	12,800	13,900	2,000	3,100

Table 11: Adjustments for medium adoption scenario

High adoption	Sites required			vs. 900 MHz result	
	900 MHz	1800 MHz	2100 MHz	1800 MHz	2100 MHz
As Ofcom	8,400	18,700	29,000	10,300	20,600
900 MHz 1 carrier - VF	11,000	18,700	29,000	7,700	18,000
Inbuilding equality - VF	11,000	14,900	17,800	3,900	6,800
HSDPA adj - say 15%	-1,700	-2,200	-2,700	-	-
Possible outcome	9,300	12,700	15,100	3,400	5,800
Outcome - 20%	7,400	10,200	12,100	2,800	4,700
Outcome +20%	11,200	15,200	18,100	4,000	6,900

Table 12 Adjustments for high adoption scenario

Existing MNO network

In calculating the cost differentials arising from re-farming Ofcom uses, as a starting point, the assumption that all operators have a pool of 6,500 existing sites. Of these, 85% are assumed to be suitable for upgrade to 3G at 900 MHz and 1800 MHz, whilst at 2100 MHz all are suitable for continued use at this frequency[15]. It may or may not be appropriate to conclude that 6,500 sites is currently the correct number, but it is of more relevance is to consider what the number in 2010 might be. Ofcom's 2G traffic/clearance scenarios will however have an impact on this:

- In Ofcom's high broadband scenario used for 2G clearance, there is an assumption that 35% of customers and traffic have migrated to 3G. As discussed elsewhere in this document[16], such a *traffic* migration is not going to happen without further investment in 3G to improve coverage/capacity in the 80% area. Since all 3G phones are also 2G capable, unless there is sufficient coverage/capacity for a call to be made in 3G, it will revert to 2G. Whilst some of this expenditure will be in adding carriers to existing sites, it is hard to envisage that the high broadband migration scenario will occur without further 3G site construction at 2100 MHz. If the other three MNOs experience a similar 3G traffic growth, they too will have increased their stock of 2100 MHz sites.

[15] Paragraph A8.30

[16] Annex 3

- In the low broadband scenario it is envisaged that 2G traffic will rise by 20%. It is hard to see how this can happen, (ignoring refarming) without the addition of new 2G sites in the 80% coverage area. This will add to the pool of sites available for upgrade. Here, all four 2G/3G MNOs will have expanded their network.

- But 2G refarming cannot be ignored. In both the high and low scenarios of Ofcom, some 2G spectrum is cleared by the accelerated transfer of demand from 2G to 3G. As before this can only be achieved by further 3G build at 2100 MHz for the two 900 MHz incumbents.

- Finally, in particular in the low demand scenario, the remaining 2G traffic can only be squeezed onto the remnant of the 900 MHz incumbent's spectrum by their construction of new 2G cell sites.

Vodafone's conclusion is that under any of Ofcom's scenarios, the available pool of sites, 2G and/or 2100 MHz 3G in 2010 will be greater than the level currently assumed, for all operators. The volume of such sites is likely to be greater for 900 MHz incumbents than for the other MNOs, and will vary by the intersection of the 3G penetration scenario and the number of carriers cleared by the 900 MHz incumbents. This needs to be taken into account when costing the potential benefit of spectrum refarming. The absence of the inclusion of this in Ofcom's modelling illustrates the disjointed nature of the separate exercises on 2G spectrum clearance and 3G refarming.

Annex 3 looks at the levels of possible practical 3G deployment by the 900 MHz incumbents in order to prevent traffic "falling back" to 2G and thus to permit 2G spectrum clearance. Annex 2 considers the volumes of 2G new build that are contemplated in some of the 2G clearance scenarios. Very conservatively, the costing analysis below looks at the impact of 500 and 1,000 additional sites built by 2010 in excess of Ofcom's assumption.

The phasing of the site builds

There are two problems with the phasing of the site builds that Ofcom has adopted in its costing model. The first is that the build programme starts unreasonably early. The second is that the deployment rates for the three scenarios are not internally consistent.

As Vodafone understands it, Ofcom's proposed timetable for refarming is an auction in 2009 and a release in 2010. The build programme that Ofcom is contemplating for the low adoption scenario is 30% in 2009/10, 50% in 2010/11 and the balance in 2011/12. Vodafone considers that this is wildly overoptimistic. In order to complete 30% of the builds and upgrades in 2009/10, i.e. immediately post auction, any prospective bidder would have had to commit substantial resources prior to the auction. This is implausible. Vodafone has

previously identified to Ofcom that the typical period to establish a new site is 12 – 24 months. It might be possible to accelerate this in the case of site upgrades, but the cost model assumes a constant ratio of upgrades and new builds in every year. Vodafone believes that at the very least the starting point for the site builds needs delaying one year.

The internal inconsistency between the three deployment rates is illustrated below. Taken from Ofcom's table 18, the scenarios are summarised in Table 13:

	2009/10	2010/11	2011/12	2012/13	2013/14
Low adoption	30%	50%	20%	0%	0%
Medium adoption	22%	33%	35%	10%	0%
High adoption	18%	22%	30%	18%	12%

Table 13: Phasing of site build

Converting these into total builds/upgrades in each year gives the results in Table 14 for the 900 MHz scenarios, using Ofcom's site numbers:

Site builds & upgrades	2009/10	2010/11	2011/12	2012/13	2013/14
900 MHz - low adoption	1,980	3,300	1,320	0	0
900 MHz - med adoption	1,650	2,475	2,625	750	0
900 MHz - high adoption	1,512	1,848	2,520	1,512	1,008

Table 14: Total builds/upgrades in each year

It is noticeable that the low adoption scenario builds more sites in the early years than either of the others. In other words, the less successful mobile broadband is likely to be, the faster 3G sites are built. This is odd. Further, Ofcom in its 2G clearance scenario links the low adoption scenario with low 3G handset penetration, (since it has a higher 2G traffic volume than the high adoption scenario). This emphasises the point that in Ofcom's scenarios, the less the sites are needed, the faster they are built. In the real world this represents an eccentric use of scarce resources. Equipment will be deployed on an as needed basis, not speculatively or in inverse relation to need.

From 2010, the volume of growth of sites will in Vodafone's view be linked to the level of 3G handset adoption and of the growth in mobile broadband demand. The most reasonable approach would be to adopt the high adoption phasing, time shifted one year, for all build scenarios. This will mean that more sites are

built in a given year in the high adoption scenario than the medium and the low i.e. when the demand is greater, as might be expected in a real world enterprise. This build programme and its implications for the three Ofcom scenario volumes are shown in Table 15:

Programme	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
	0%	18%	22%	30%	18%	12%
900 MHz - low adoption	0	1,188	1,452	1,980	1,188	792
900 MHz - med adoption	0	1,350	1,650	2,250	1,350	900
900 MHz - high adoption	0	1,512	1,848	2,520	1,512	1,008

Table 15: Implications for the three Ofcom scenario volumes

Indicative benefit calculations

Finally, it is possible to put together the possible Vodafone site numbers for the 80% area from the tables above, with the Vodafone site build programme from Table 15, and a revised estimate of the stock of sites in 2010 and run these through the costing model. Unit costs per site per year are taken from Ofcom's table 17. Ofcom has explained in its supplementary disclosure[17] the basis of the costs per site per year calculation. Vodafone has attempted to check these, using its interpretation of Ofcom's response to Q1 in that document. Vodafone's calculations suggest that some of the cost outputs at 3.5% reported by Ofcom may not be consistent with its method[18], but that the results for 11.5% cost of capital seem generally consistent with the method, except for 2012/13 update cost, which appears to be £30k not the £25k quoted by Ofcom. Although not supplied by Ofcom, present values for the build and upgrade costs for 2014/15 at 11.5% can be derived by interpolation, at £80k and £20k respectively.

The product of site volumes, site build programme and unit costs gives the results[19] shown in Table 16:

[17] Answers to stakeholder questions relating to cost modelling, November 2007

[18] New builds would seem to have been transposed by one cell – the cost cited as 2009/10 would seem to be that of 2008/09 and so on.

[19] To be clear, the last two scenarios take the core "possible outcome" set of sites and overlay it with not 6,500 existing sites, but 7,000 and then 7,500 sites, as a result of network build up to 2010.

	1800 MHz vs. 900 MHz			2100 MHz vs. 900 MHz		
	Low	Medium	High	Low	Medium	High
	£m	£m	£m	£m	£m	£m
Ofcom volumes at 3.5%	878	1,337	2,282	1,090	1,758	4,008
Ofcom volumes at 11.5%	481	711	1,179	568	906	2,044
Add VF build rate	390	605	1,056	478	786	1,841
Only one 900 MHz carrier	226	400	789	314	581	1,575
In building loss equality	103	184	400	-65	7	427
Outcome with HSDPA adj	102	174	348	-65	-4	324
Outcome - 20%	82	143	287	-106	-55	212
Outcome + 20%	123	205	410	-24	47	437
Outcome +500 sites by 2010	102	174	348	-85	-24	303
Outcome +1000 sites by 2010	102	174	348	-106	-45	282

Table 16: Indicative benefit calculations in 80% area

These calculations suggest that there is very little cost advantage to be obtained from refarming 900 MHz vs. 2100 MHz under the low or medium broadband adoption scenarios. This is not to deny that there is some benefit in the abstract. A defect of the model is that it is assuming that an operator would deploy an entire new coverage layer at 900 MHz or 1800 MHz: this is generating the negative results of the low and medium scenarios, which are comparing the costs of building new sites at 2100 MHz with the costs of a mix of building new sites and upgrading all existing stock at 900 MHz or 1800 MHz. It is possible that an operator may be able to attempt to minimise its incremental cash outlay by using the lower frequencies for infilling coverage holes rather than providing a complete layer, as far as is physically possible, so that the outcome could be a mixed 900 MHz and 2100 MHz (or 1800 MHz and 2100 MHz) coverage layer. Here the number of sites that would be built would be greater than the model is predicting, but the numbers of sites to be upgraded would decrease against the prediction. It is not clear at this point how practical such a mixed coverage layer would be to operate: the quality of inter-frequency handovers might prove a major obstacle. An alternative might be to recycle equipment so that the coverage layer was 900 MHz in some regions and 2100 MHz in others. All of this is unclear. Quite how different the total costs of the 900 MHz or 1800 MHz options (and hence their difference from the total costs under the 2100 MHz option) would be as a result of this strategy is impossible to estimate from Ofcom's methodology.

Comments to Annex 7: Effects of frequency on provision of 3G services in less densely populated areas

Analysis of Ofcom scenarios

Ofcom's table 22 shows its view of the number of sites and the cost involved in extending coverage from 80% to 99% at the various frequencies: Vodafone repeats these numbers in Table 17 below, and shows the costs at the 11.5% cost of capital that Vodafone believes to be more appropriate for cost benefit analysis.

	Difference 900 MHz vs. 1800 MHz	Difference 1800 MHz vs. 2100 MHz	Difference 900 MHz vs. 2100 MHz
Site numbers	1,400	1,400	2,700
Additional costs £m at 3.5%	130	130	250
Additional costs £m at 11.5%	76	76	148

Table 17: Benefits at 11.5% v 3.5% cost of capital, rural area

The benefit differential at 11.5% is clearly substantially less than at 3.5%.

An implicit assumption in the estimates of the benefits of UMTS900 over UMTS2100 is that 3G coverage will be built out from 80% all the way to 99% irrespective of the cost, at either 2100 MHz or 900 MHz. In reality operators will only build coverage where they judge it economic for them to do so, i.e. where the benefits from complementing their existing 2G network with a 3G network exceed the costs of doing so. Clearly one of the variables to such a calculation is the volume of 3G specific services: thus one might expect that under Ofcom's high broadband adoption scenario a greater level of rural 3G penetration would be likely to be achieved than under the low adoption broadband scenario, where there is no obvious case at all for 3G build beyond the 80% coverage level, whilst 2G coverage continues. The fact that the costs of extending coverage from 80% - 99% may be lower at 900 MHz than at 2100 MHz does not necessarily mean that it will be profitable for the operator to extend coverage over the last few percent at either 900 MHz or 2100 MHz, particularly given the continuing existence of 2G coverage that extends to 99%. Two approaches to this issue are more appropriate.

- In the first instance assume that it is only economic to extend coverage at 900 MHz to a lower level, say 95%. Here some scaling to both the 900 MHz and 2100 MHz costs should be undertaken when comparing the benefits of 900 MHz vs. 2100 MHz. Ofcom's sensitivity analysis in Figure 21 on page 189 suggests that building both 900 MHz and 2100 MHz out to only 95% population coverage reduces the cost differential from £250m to about £130m at 3.5%. The detailed methodology supplied by Ofcom in its supplementary document enables Vodafone to calculate this at 11.5% - the result is a reduction of the differential from £148m to £80m.

- In the second instance, assume that the level of economic coverage would be less at 2100 MHz than at 900 MHz. Here a valid evaluation of the relative benefits should be based on the loss of 3G coverage for a number of operators.

Under neither method is it appropriate to consider an axiomatic extension of coverage to 99%. For the purposes of this exercise, Vodafone has assumed that it is more reasonable to assume a coverage level for 3G of 95%, rather than 99%. Given the conclusion that the degree of coverage beyond 80% is related to the growth of mobile broadband, Vodafone has also calculated, using Ofcom's site numbers, the cost of a coverage rollout only to 90% - this might be more appropriate at lower levels of broadband demand.

A further modification to Ofcom's scenario relates to the rate of site build. The build programme that Ofcom is contemplating for 80%-99% coverage extension is 30% in 2009/10, 50% in 2010/11 and the balance in 2011/12. Vodafone considers that this is premature. In order to complete 30% of the builds and upgrades in 2009/10, i.e. immediately post auction, any prospective bidder would, as for the 80% coverage area, have had to commit substantial resources prior to the auction. This is implausible. Vodafone has previously identified to Ofcom that the typical period to establish a new site is ✂. It might be possible to accelerate this in the case of site upgrades, but the cost model assumes a constant ratio of upgrades and new builds in every year. The timeline for 3G rollout also overlaps with that of the 80% coverage area: both programmes would in practice be competing for the scarce resources of the network operator in planning and deployment. Ofcom proposes an alternative timeline – that of 30% in 2011/12, 50% in 2012/13 and 20% in 2013/14. Vodafone believes this is still too aggressive given that the benefits of rural deployment are likely to be at best marginal, and suggests an alternative of 20% in 2010/11 and then equally over the next four years.

Modelling these changes gives the results for 900 MHz vs. 2100 MHz shown in Table 18:

(The 99% coverage at Vodafone's suggested build rate is £94m at 11.5%.)

	Difference 900 MHz vs. 2100 MHz	
	At 3.5% £m	At 11.5% £m
Ofcom to 99% coverage	250	148
Ofcom site numbers to 95% coverage	134	80
Ofcom site numbers to 95% coverage, Ofcom slower build rate	115	60
Ofcom site numbers to 95% coverage, Vodafone build rate	114	51
Ofcom site numbers to 90% coverage, Vodafone build rate	55	25

Table 18: Benefits at 11.5% v 3.5% cost of capital for different coverage percentages, using Ofcom site numbers

Referring to Ofcom's site numbers in Annex 7, Figure 20, Vodafone does not believe that the difference in site numbers calculated for 1800 MHz v 2100 MHz (1,400) is reliable compared with the difference calculated for 900 MHz v 1800 MHz (1,400) considering the relative frequency differences in each case.

Vodafone site numbers calculation

The above exercise has used Ofcom site numbers. However Vodafone's believes that Ofcom has overstated the number of sites that would be required to acquire 3G coverage at all frequencies and as a result overstated the absolute difference between 2100 MHz and 900 MHz. The basic principle adopted by Ofcom to estimate the costs of providing 3G services to less densely populated areas is to plan a small sample area and extrapolate the results to the 80-99% population areas of the UK. Ofcom's structure for the high level modelling is outlined in the flow diagram of its Figure 18. The key physical parameters that affect the cost output from the algorithm are the following:

a) The cell density required for each frequency;

b) The percentage of sites that are upgraded.

To estimate the cell density required for each frequency, Ofcom has analysed a sample area in West Sussex and re-planned it for 3G using 900 MHz, 1800 MHz and 2100 MHz to estimate the cell densities shown in its Table 20. Ofcom has provided the link budgets used for this planning exercise to Vodafone.

A6.4 outlines Ofcom's definition of "basic outdoor coverage" by which the 80% licence requirements of 3G operators will be measured. A6.5 states: *"In less densely populated areas of the country, the primary aim of further investment is assumed to be increasing the extent of basic outdoor coverage. The costs associated with extending the population covered by 3G networks beyond 80% are examined in Annex 7."*

However, Ofcom's link budgets[20] contain errors and are not consistent with A6.4 and A6.5 and therefore assume a higher level of coverage than "basic outdoor coverage". Consequently, the cell densities in Table 20 over-estimate the number of sites required for "basic outdoor coverage" by Ofcom's own definition of this level of coverage.

The key areas where Ofcom's link budgets are incorrect are as follows:

1. The link budgets for 900 MHz, 1800 MHz and 2100 MHz include vehicle/in building penetration losses. These are inconsistent with outdoor coverage. The values should be 0 dB. Notwithstanding this, the values are also inconsistent with Ofcom's own assumptions in Annex 8. Vodafone also does not believe that there is a substantial difference between in building losses at 900, 1800 and 2100 MHz and has provided measured evidence to Ofcom to show this.

2. Ofcom has assumed incorrect receiver sensitivity for UMTS900 UE relative to UMTS1800 & UMTS2100 UE. The UMTS900 UE sensitivity is relaxed in the 3GGP specifications[21] by 3dB to account for the narrower duplex spacing of the 900 MHz frequency bands.

3. It is unclear what uplink bit rate has been assumed by Ofcom. Assuming a 128/384 UL/DL service, Vodafone believes that the downlink will be the limiting factor.

In order to correct for these errors, Vodafone has derived its own estimates of the site numbers required at each frequency under consideration. Vodafone has assumed a downlink limited 128kbps/384kbps outdoor service with the geotype distributions for the 80%-99% population areas summarised in Table 19:

Geotype	Area/km^2
Quasi open rural	95,172
Open rural	90,857
TOTAL	**186,029**

Table 19: 80-99% population area geotype distributions

[20] Answers to stakeholder questions relating to cost modeling, November 2007.

[21] 3GPP TS21.101 Release 6.

Vodafone has estimated the number of sites required at 900 MHz, 1800 MHz and 2100 MHz in less densely populated areas assuming:

✂

The results are summarised in Table 20 and Table 21.

	2100 MHz Cell range (km)	1800 MHz Cell range (km)	900 MHz Cell range (km)
Open rural	✂	✂	✂
Quasi open rural	✂	✂	✂
	Cell Area (km^2)	**Cell Area (km^2)**	**Cell Area (km^2)**
Open rural	✂	✂	✂
Quasi open rural	✂	✂	✂

Table 20: Link budget estimation of frequency on cell range and site areas (Rural)

	2100 MHz Node B (#)	1800 MHz Node B (#)	900 MHz Node B (#)
Open rural	✂	✂	✂
Quasi open rural	✂	✂	✂
Total	✂	✂	✂

Table 21: Number of sites required for extending coverage from 80~99% population

According to Vodafone's analysis, when extending coverage from 80 to 99%, the number of base stations required using 1800 MHz spectrum is ✂% greater (c/f +60%, source: Ofcom) than the number needed for 900 MHz spectrum; whilst the number of 3G base stations required using 2100 MHz spectrum is ✂% greater (c/f +120%, source: Ofcom) than the number needed for 900 MHz spectrum.

Vodafone has also estimated the site numbers for other population coverage percentages in Table 22:

Population Coverage	2100 MHz Node B (#)	1800 MHz Node B (#)	900 MHz Node B (#)
80-90%	✂	✂	✂
80-95%	✂	✂	✂

Table 22: Number of Node B required for 80-90% and 80-95% population coverage.

The differences of 1800 MHz and 2100 MHz to 900 MHz compared to Ofcom's estimates are summarised in Table 23:

	900 MHz vs.	
	1800 MHz	2100 MHz
80% to 99% coverage		
Ofcom	1,400	2,700
Vodafone	✂	✂
80% to 95% coverage		
Ofcom	731	1,463
Vodafone	✂	✂
80% to 90% coverage		
Ofcom	352	705
Vodafone	✂	✂

Table 23: Site numbers per Vodafone - 80% to 99% coverage

Finally, the present value of the cost benefit of 900 MHz compared to 2100 MHz for different population coverage levels is summarised in Table 24, using Ofcom unit costs at 11.5% and the Vodafone site build rate from the section above:

	Ofcom	Vodafone
	£m	£m
80% to 99% coverage	94	✂
80% to 95% coverage	51	26
80% to 90% coverage	25	✂

Table 24: Differential costs: at 11.5%, 2100 MHz vs. 900 MHz using VF build rate

Vodafone's overall conclusion is that the present value of the practical benefit of 900UMTS over 2100UMTS beyond the 80% coverage area is likely to range from zero in the case of the low broadband adoption scenario to no more than £26m at maximum per operator[22], depending upon the degree of adoption of profitable 3G specific services. This is an order of magnitude smaller than Ofcom's estimate of £250m.

Output Summary

Putting together the rural and the 80% coverage areas gives the following results per operator:

		Ofcom at 3.5%, £m			Vodafone at 11.5%, £bn		
		To 80%	Rural	Total	To 80%	Rural	Total
Low broadband adoption	**900 MHz vs. 1800 MHz**	900	250	1,150	102	0	102
	900 MHz vs. 2100 MHz	1,100	250	1,350	0	0	0
Medium broadband adoption	**900 MHz vs. 1800 MHz**	1,300	250	1,550	174	19	193
	900 MHz vs. 2100 MHz	1,700	250	1,950	0	26	26
High broadband adoption	**900 MHz vs. 1800 MHz**	2,300	250	2,550	348	19	367
	900 MHz vs. 2100 MHz	4,000	250	4,250	324	26	350

Table 25: Relative costs for the UK, Ofcom and Vodafone

[22] H3G have stated that they have already extended their population coverage beyond 80%, so any further investment/differential benefit accruing to them would be further restricted.

(Negative values from Table 16 above have been entered as zero.) These values form the basis of Table 1 in the summary at the head of this annex.

Annex 2 - Critique of the cost of investment in 2G to clear spectrum: missing costs, cost underestimates, and failure to capture risks.

Clearance methodology

Clearance of 2G spectrum for refarming can be addressed by two means. Investment in 2G so that existing or increased 2G traffic can be accommodated in a smaller amount of spectrum, and/or reducing the level of demand on 2G, by "natural" or accelerated migration across to 3G, so that the clearing effort required on 2G is reduced. It is possible to conceive of a scenario where use of only one of these methods may be employed: in reality however it is likely that most outcomes will require a combination of both.

Ofcom's clearance scenarios generally use both means:

- In the high 3G demand, clear three scenario, where 35% of traffic is deemed to have naturally migrated to 3G, and 2G traffic levels are as 2006, clearance costs of £150m are planned to be exclusively on 2G. In other scenarios some element of migration to 3G is included:

- In the clear three low demand scenario where only 15% of the traffic is deemed to have migrated to 3G, and 2G traffic levels in 2010 are 20% above 2006, £350m of 2G clearance costs and £400m of accelerated migration to 3G is contemplated.

- In the clear five high demand scenario, £350m of 2G clearance costs and £450m of accelerated migration to 3G is planned.

- In the clear five low demand scenario, which Ofcom does not formally model since it finds the costs unacceptable, £500m of 2G clearance costs and approximately £1,350m of accelerated migration to 3G is planned.

Whilst supportive of the overall methodology, Vodafone finds Ofcom's approach defective since it assumes that merely providing customers with 3G handsets (in either "natural" or accelerated migration) is sufficient to ensure that their calls will be carried on 3G. In reality 3G network investment is required as well. This issue and the appropriate level of 3G investment is discussed in Annex 3.

In Annex 2 below, Vodafone considers the level of investment that would be required on 2G where either three or five carriers are being cleared and where 2G traffic is either the same as 2006/07 (the high broadband adoption scenario) or 20% above 2006/07 levels (the low broadband adoption scenario). ✂.

The likely overall costs of 2G clearance, i.e. the collective costs of 2G investment, 2G>3G accelerated migration, and 3G investment, are considered and summarised in Annex 4.

Summary of 2G clearance costs by way of 2G investment

In this annex, Vodafone analyses Ofcom's 2G cost calculations and estimates the costs of clearing and releasing 900 MHz spectrum. In summary:

1. Ofcom's 2G capacity analysis is defective since;

    - It makes unrealistic assumptions, which overestimate 2G network capacity to the extent that the 2G spectral efficiency postulated in Annex 9 is higher than the 3G spectral efficiency implied by Ofcom's 3G analysis in Annex 8.

    - It ignores the key practical factors which reduce the efficiency with which spectrum can be used for GSM networks.

    - It ignores the fact that, as the amount of 900 MHz spectrum an operator has for 2G is reduced, the efficiency with which the spectrum can be used and the capacity available from it reduces disproportionately to the amount of spectrum removed.

2. In its calculations, Ofcom has failed to identify key costs, processes and risks associated with the release of 900 MHz spectrum for 3G networks.

3. ✂

4. ✂.

✂

Ofcom Scenarios for mobile broadband (A9.14-A9.17)

Under Ofcom's provisional conclusions from the consultation, there is a potential choice available for a 900 MHz operator: both operators must clear and release at least 1.5 carriers (7.5MHz) currently used for 2G so that Ofcom can award three 5MHz licences to non-900 MHz incumbents, but each 900 MHz operator could in addition choose to clear a further 5MHz, so that there is a carrier available for the operator's own use in 3G. These two options (for Vodafone) are summarised in Table 26 and Table 27 below.

Spectrum band	Allocated to 2G	Allocated to 3G	Total spectrum
900 MHz	9.9 MHz		9.9 MHz
1800 MHz	5.8 MHz		5.8 MHz
2100 MHz		14.8 MHz	14.8 MHz

Table 26: 900 MHz operator spectrum usage – 3 block release only

Spectrum band	Allocated to 2G	Allocated to 3G	Total spectrum
900 MHz	4.9 MHz	5MHz (re-farmed)	9.9 MHz
1800 MHz	5.8 MHz		5.8 MHz
2100 MHz		14.8 MHz	14.8 MHz

Table 27: 900 MHz operator spectrum usage – 3 block release, 2 block re-farming

Ofcom has examined ways of clearing the 2G spectrum and come up with a set of actions that it believes would have to be undertaken. Precisely which of the set would be required and the cost of each is dependant on two variables: the volume of 2G traffic that the operator has assumed it will have to accommodate (i.e. the forecast total of voice traffic less forecast to be "naturally" carried on 3G[23]) and the amount of 2G spectrum remaining to the 900 MHz operator: i.e. the variables are the volume of the "quart" and the size of the "pint pot" into which it must be squeezed.

Ofcom considers two scenarios related to the release and re-farming of spectrum (A9.15).

- A high demand for broadband scenario where 2G traffic levels in 2010/11 are similar to those observed in 2006/07 since 35% of customers have 3G capable handsets and it is assumed that their traffic, both voice and data is carried on 3G.
- A low demand for broadband scenario where 2G traffic levels are 20% higher than those observed in 2006/07. This higher 2G traffic results from lower penetration of 3G capable handsets (15% per Ofcom table 7). Here it is assumed that the 900 MHz operators are only

[23] Without any accelerated migration to 3G to ensure 2G traffic demand is constrained

interested in using 900 MHz for GSM, hence they do not re-farm: also no other operator seeks to use 900 MHz for 3G, making any clearance exercise pointless.

Vodafone examines in turn each of the methods that Ofcom has employed in its desktop analysis to achieve these scenarios, but first there is an overall point to be made on certainty. Ofcom happily assumes that the measures it suggests will be sufficient to clear the required quantum of spectrum and also states in 11.35:

> *"Although mobile operators are likely to have incentives to minimise quality problems, some unavoidable transitional problems might remain, due for example to the potential risks of introducing new technologies into the network."*

✂.

✂..

All this must be done inside two years without adversely impacting the overall customer experience with the consequent immediate loss of competitive advantage. ✂.

✂

Ofcom's theoretical capacity analysis (A9.68-A9.100)

Ofcom performs a theoretical capacity analysis of a GSM network to estimate the capacity of an idealised network (A9.70-A9.81). The analysis is used to demonstrate the extent to which reducing the amount of spectrum available for GSM impacts on a network's ability to carry traffic. Ofcom then uses the outputs of this analysis to estimate the cost impacts of operating GSM networks in a reduced amount of spectrum.

Ofcom's theoretical analysis is simplistic and flawed in a number of areas, which leads to an overestimate of the achievable capacity of a GSM network operating with a given amount of spectrum and an underestimate of the costs and complexities involved. ✂.

A theoretical GSM capacity analysis cannot be applied to real world networks to estimate the costs of spectrum removal, since the key practical factors which limit network capacity and practical frequency re-use have been ignored. These factors are summarised below:

- Site antenna heights differ in real networks due to terrain conditions, site locations and the presence of umbrella coverage sites.
- Site positions do not conform to an idealised grid, since it is not possible to acquire sites in this manner. Sub-optimal site location compromises have to be accepted in the real world.

- Traffic density is not uniform, but has significant localised peaks, even when the average traffic density is high. Networks have to be constructed to carry the actual traffic offered at different locations within it; this has implications on the use of spectrum.
- Propagation is not uniform across an area, but dependent on localised clutter, which means that cells are far from hexagonal with RF radiation from some cells causing localised interference at distant unexpected points within the network.
- Fragmented, small blocks of spectrum limit the practical re-use factors and network performance that can be achieved, since BCCH channels have to be planned with adjacencies with small spectrum blocks.

✂

Cost of releasing 7.5 MHz of spectrum

In this section, Vodafone estimates the cost of clearing and releasing 7.5 MHz of spectrum. ✂

Risks to Vodafone and Vodafone's customers

Ofcom assumes that spectrum release could be achieved by 2010. However, Ofcom has not considered the extent of the changes involved, nor the processes involved with introducing new network features.

The typical steps for introducing a new network feature are summarised in Table 28.

Task	Purpose
Laboratory integration testing	Laboratory testing of new feature to ensure that it inter works correctly with hardware and handsets deployed in the Vodafone network.
Hardware upgrades	Perform any necessary hardware upgrades necessary to utilise the feature. This may also include new site build, if this is necessary for additional capacity due to 2G spectrum reduction.
First site implementation	A small live test implementation of the feature to ensure that it does not degrade performance of the network.
Network monitoring	Monitoring on network performance to ensure that there is no network performance degradation. (1-3 months depending on complexity of feature).
Plan full implementation	Assemble/procure resources for full deployment. Plan implementation to minimise risks of adverse impact to network.
Network wide rollout	Deployment to all network nodes.

Table 28: Typical steps for introducing a new network

During a period of new feature introduction, Vodafone would maintain stability across the network. (I.e. it would not introduce other new features at the same time.) If, at any time during feature network rollout period, performance issues related to the feature were identified, Vodafone would either de-activate the feature, in case of serious issues, or perform optimisation of the feature to achieve acceptable performance levels. A de-activation of the feature could result in restarting the process, dependent on the issues identified.

It is not uncommon for infrastructure issues to be identified during network rollout, that subsequently require software corrections from vendors. Feature introduction then re-commences at the laboratory integration phase.

Ofcom has not considered that:

- It would not be practical to remove the interleaving of spectrum in parallel with engineering wholesale spectrum clearance. The steps that Ofcom is considering are each individually highly disruptive, requiring wholesale hardware changes (in the case of SFH); the implementation of new software features; the acquisition and build of new sites and major internal programmes to deliver them. It is likely that O_2 would be similarly affected. The levels of coordination necessary between the two (competing) companies would be extreme and any misunderstandings or delay on the part of one operator would result in mistakes (with consequent QoS impacts) and/or delays in the project timescales for both. Vodafone believes that the removal of interleaving and the clearance of spectrum would need to be separated in time.

- The extent of the 2G changes proposed by Ofcom would necessitate the introduction of numerous new features during the re-engineering period.

- The acquisition and build of new sites in the busiest parts of Vodafone's network could take up to 2 years to achieve. In some areas, e.g. Central London, it may not be possible to acquire the sites at all, forcing an unacceptable increase in congestion and dropped calls.

- Site build operates on a ✂ rolling acquisition and build cycle. Acquisitions are necessary in the preceding final year to enable sites to be built in volume in the following financial year. It would take two financial years to ramp up to an appreciable volume of site builds.

- Procurement cycles for significant volumes of new equipment are not immediate.

- Acquisition of new sites and extensive base station hardware upgrades would be needed to be completed *before* any re-tunes and re optimisation of the network could take place. Hence optimisation is back end loaded in any implementation programme, such that the real issues that affect performance and capacity would not be evident until late in the programme.

- The extent of the engineering changes required introduces risks factors, which cannot be identified today, that will hamper Vodafone's ability to achieve acceptable capacity and quality of service during the re-engineering of its network.

- The majority of Vodafone's limited technical and deployment resources would be directed to 2G engineering activities of squeezing a quart into a pint pot at the expense of 3G development and optimisation.
- With changes of this magnitude, degradation in Quality of Service will inevitably occur. Vodafone experience with large area frequency retunes shows that there are always inaccuracies that require clean up activities after implementation. The length of time to clean up is governed by the complexity of the frequency plan. Although optimisation activities have been factored into the overall estimation, there will invariably be an impact on ✂. This is a risk that is difficult to quantify in monetary terms but it will impact the brand and Vodafone's competitiveness in the market place.

Vodafone believes that a re-engineering exercise of this magnitude could not be achieved in the timescales proposed by Ofcom.

✂

The impact of clearing 12.5MHz and releasing 5MHz of 900 MHz spectrum

In this section, Vodafone assesses the impacts of clearing 12.5MHz and releasing 7.5MHz of 900 MHz spectrum, i.e. keeping 5MHz for own 3G use.

✂

Annex 3 – Investment in 3G network and handsets to permit 2G spectrum clearance

Summary

This Annex critiques Ofcom's '3G strategy' of moving traffic to 3G networks by accelerating the take up of 3G handsets and deploying additional UMTS2100 base stations outside of areas already covered by 3G.

Vodafone believes that the Ofcom assumption that traffic displaced from 2G networks can be carried on the 3G networks without further expenditure on extra coverage and capacity for 3G is fundamentally flawed. Ofcom has ignored in its scenarios the costs necessary to upgrade Vodafone's existing 3G network to provide indoor coverage for users within 80% population regions to prevent traffic "falling back" to 2G. The required outlay on 3G varies depending upon the scenario adopted. At one extreme is a scenario that contemplates no traffic migration to 3G, i.e. all expenditure on 2G clearance is incurred to squeeze existing and future (+20%) traffic volumes onto 2G. Here no 3G expenditure is likely to be incurred. At the other extreme, it is possible to conceive of a 2G clearance strategy which does relatively little on 2G, but instead concentrates on pushing the vast majority of demand onto 3G. Here substantial expenditure both on 2G>3G handset migration and on 3G investment at 2100 MHz would be required.

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Annex 4 – Summary of the overall costs and benefits of 2G spectrum clearance

Summary

The previous Annexes have examined the costs and benefits of the various elements of 2G spectrum clearance:

- Annex 1 has reviewed the benefits of the use of one carrier at 900 MHz vs. available spectrum at 1800 MHz and 2100 MHz. Vodafone has concluded that the benefits of 900 MHz have been grossly overstated by Ofcom.
- Annex 2 has considered the costs of additional investment in 2G at varying levels of traffic and carrier clearance.
- Annex 3 has considered the costs that result from restricting 2G traffic volume, i.e. accelerated 2G>3G handset migration and 3G investment, under various scenarios. Here Ofcom have omitted a substantial body of cost.

This annex attempts to draw together the separate costs for the two spectrum clearance elements i.e. expenditure on 2G and on 3G, and considers the level of overall expenditure required by the 900 MHz incumbent operators under various traffic and clearance scenarios, for both Ofcom and Vodafone views of the level of costs. Ofcom's two separate scenario variables are applied; clear three or five carriers (7.5MHz or 12.5MHz per operator) and low or high broadband penetration (2G traffic in 2010 is 20% above 2006/07 levels or at 2006/07 levels). The annex concludes by bringing together Vodafone's view of the benefits of refarming from annex 1, to draw up a picture of costs and benefits for the industry as a whole.

Ofcom view of costs and benefits

Ofcom's view of costs (for the two 900 MHz incumbents combined) can be taken from its tables 54 and 55, and is shown in Table 29 below.

Carrier clearance and demand permutations		2G investment £m	2G>3G handset migration £m	3G investment £m	Total £m
Clear three	**Low demand**	£350m	£400m	Ignored	£750m
Clear three	**High demand**	£150m	Nil	Ignored	£150m
Clear five	**Low demand**	£500m	£1,350m	Ignored	£1,850m
Clear five	**High demand**	£350m	£450m	Ignored	£800m

Table 29: Ofcom spectrum clearance costs, ignoring 3G investment

The clear five low demand scenario is not explicitly modelled by Ofcom on the grounds that the *"incremental which would be imposed by such an approach would be very significant …. and it is more difficult to estimate the costs for this amount of release accurately."*, so it is extrapolated by Vodafone from the clear four scenario in table 54. However, as discussed in Annex 3, these scenarios are defective in that traffic will not be actually carried on 3G merely as a result of handset migration, without investment in 3G:

- The clear three low demand scenario assumes £400m of handset migration: there will be no matching traffic migration without 3G network investment.
- The clear three high demand scenario does not require handset migration as part of the clearance scenario, but relies on a capping of 2G demand resulting from a higher penetration of 3G capable handsets than the low scenario: again this will require 3G investment to prevent the traffic demanded by customers with 3G capable handsets falling back to 2G.
- The clear five scenarios both involve substantial accelerated handset migration and thus also require 3G investment.

The precise level of any such investment is unclear.

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Vodafone view of costs and benefits

Vodafone believes that Ofcom has underestimated the costs of clearing, and overestimated the benefits of refarming. ✂.


vodafone

Annex 5: A critique of Ofcom's rejection of Option A

This section discusses Ofcom's analysis of the current holders' incentives to sell 900 MHz spectrum under Option A of its spectrum liberalization consultation. Ofcom's approach is to reject Option A (*Liberalisation in hands of incumbents*) on the grounds that such an option would be unlikely to result in trading of 900 MHz spectrum, because of the competitive advantage that 900 MHz spectrum provides to the current holders.

In this Annex we focus on Ofcom's arguments as to why trade of 900 MHz spectrum may not occur, taking into account the potential impact of trading on the competitive position of different operators. Whether such trading occurs or not however, will depend crucially on the costs to the holders of 900 MHz spectrum of releasing it, and the benefits to potential acquirers. Absent any impact on the relative competitive position of different operators, if the benefits are small and the costs large, trading would not occur – and this would be the efficient outcome.

Ofcom builds its argument in steps, by first assuming a simple scenario and progressively adding complexity to it. It first considers a hypothetical situation in which each current holder of 900 MHz spectrum (which we will call an "incumbent" in what follows) does not consider the likely actions of the other incumbent when deciding whether or not to sell part of its spectrum to a non-900 MHz operator (which we call an "entrant" in what follows). We will call this situation the "non-strategic scenario". It then goes on to consider a scenario in which each incumbent behaves strategically and considers the likely reaction of the other incumbent when deciding whether to sell. We call this second scenario the "strategic scenario". Ofcom argues that the results in the strategic scenario are different depending on whether we consider a one-off interaction between the incumbents (the "static strategic scenario") or repeated interactions between the incumbents (the "repeated strategic scenario").

Non-strategic scenario

In the non-strategic scenario (i.e. in the scenario where Ofcom considers only the decision of one incumbent in isolation, disregarding the likely reaction of the other incumbent), it is important to distinguish between two cases.

In the first case the sale of one block of 900 MHz spectrum to one or more non-900 MHz operators by one or both of the incumbents (Vodafone and O2) would not have the effect of increasing the intensity of competition in the market for 3G mobile phone services. If the sale of one block of 900 MHz spectrum implies that the cost savings achieved by the entrant are so large to make its total gains (new sales + cost savings) larger than the amount lost by the incumbent (lost sales + possibly some costs of redirecting its calls

traffic), the entrant is willing to pay a price for the block that exceeds the costs to the incumbent and the block would always be traded.

Ofcom considers also a second non-strategic case in which the transfer of a block of 900 MHz spectrum to one or more non-900 MHz operators by one or both of the incumbents (Vodafone and O2) would increase the intensity of competition in the market for 3G mobile phone services. As a consequence the total profits earned by all the operators in the sector would fall (before considering the cost savings that the entrant could achieve as a consequence of the transfer). This means that the additional amount of profits earned by the buyer of the block (before considering the cost savings that it can achieve) is less than the profit loss experienced by the incumbent as a consequence of the increase in competition. If the cost savings achieved by the buyer are not sufficiently large as to make the total amount gained by the buyer (additional profits + cost savings), and therefore the price that the buyer is willing to pay for the block, greater than the incumbent's loss, the block is not going to be traded.

In these scenarios, which of the two cases are more realistic and whether there will ultimately be trade or not depends on the exact magnitude of:

- the cost savings for the buyer(s),
- the cost to the incumbent of reducing its spectrum, and
- the potential loss to the incumbents from the increased intensity of competition.

The first two are addressed by Ofcom in its cost-benefit analysis. In relation to the third driver, Ofcom states that its initial view is that the value of the change in competitive intensity could be large. There is no evidence however presented as to why this could be expected to be the case. In Chapter 6, Ofcom states that *"it is possible, that asymmetric access to 900 MHz spectrum could lead to lower competitive intensity"*. As discussed in the critique to Annex 10 (see Annex 6), Ofcom's choice of economic model to try and evaluate the potential impact of asymmetries on competition effectively assumes the result, rather than proves it. Furthermore, the potential impact on competitive intensity is only relevant in the high demand (and arguably medium demand) scenario. Ofcom has also declared that the mobile market is effectively competitive, despite its belief that cost asymmetries exist between the current holders of 900 MHz spectrum and 1800 MHz spectrum which, in the past, it has used to justify asymmetric termination rates. It is not therefore clear why Ofcom considers that in the 3G market, there could be potentially significant losses to the current holders of 900 MHz spectrum from an increase in competitive intensity.

Static strategic scenario

In a strategic scenario each incumbent considers the likely reaction of the other incumbent when deciding whether to sell or not. In particular, since it is likely that the first 900 MHz block put on the market will fetch more than the second block, Ofcom recognises that – in situations in which the incumbents interact very sporadically (for the sake of simplicity this can be assumed to mean that they interact only once) – a "prisoner's dilemma" situation may arise in which each incumbent may try to sell before the other. This race to be the first to sell could lead both incumbents to sell, even though their profits would be lower than if neither had sold in the first place.

To understand the conditions under which this prisoner's dilemma outcome arises, consider Table 30 below which sets out an example with hypothetical profits for each incumbent from any possible combination of actions (i.e. "sell" vs. "don't sell decision"). The first number in each cell is Vodafone's profits whilst the second number is O2's profits. For example if neither Vodafone nor O2 sell, each of them makes a profit of 110, whilst if Vodafone does not sell and O2 does, Vodafone earns 50 whilst O2 earns 120.

		O2	
		Don't Sell	**Sell**
Vodafone	**Don't Sell**	110,110	50,120
	Sell	120,50	75,75

Table 30: Prisoner's dilemma

In this static case – in which the incumbents interact only once and each party prefers to sell even when the other party does not sell – the only possible outcome is for both parties to sell. To see this consider the situation in which Vodafone expects O2 not to sell (left column): Vodafone's best response is to sell, since by doing so it would earn 120 instead of 110 if it did not sell. Therefore having both parties not selling is not a possible outcome. Consider now the situation in which Vodafone expects O2 to sell (right column): in this case Vodafone is better off by also selling, since by doing so it would earn 75 instead of 50. A similar

reasoning will be followed by O2 and both parties will end up selling[24]. Note that for this prisoner's dilemma situation to arise, each player would find it attractive to sell if the other did not, although in the end both players end up selling and being worse off than in a situation in which neither sold.

Repeated strategic game

Ofcom then argues that looking at strategic interactions between firms, as part of a repeated game, is likely to provide a better representation of competition in the mobile market than a one-shot interaction. Ofcom therefore considers a situation in which the incumbents interact repeatedly. With repeated interaction, they could find it easier to sustain an outcome of tacit collusion in which neither incumbent sells even if both incumbents would have sold in a static game like the one in the example presented above. Ofcom bases its claim on a stream of economics and game theory literature which argues that this tacitly collusive outcome becomes possible if each party can credibly threaten the other to retaliate in the future if the second party does not cooperate. It points out that two conditions are necessary for this threat to sustain a collusive outcome:

- the parties must be deterred by the threat, which is the case if the future profits are sufficiently important relative to the profit that could be earned by deviating in the short term. For example, a firm that is only going to be around for a short period is unlikely to be deterred by future punishments; and
- the threats must be credible, in the sense that, after one of the parties has deviated, the other party must still find it optimal to punish it, given that punishment can be very costly also for the punisher.

Both conditions are likely to be satisfied if the payoffs are like in the example given in Table 30 above. In particular, if in a given period of time (today, say) Vodafone deviated from the tacitly collusive outcome and sold, whilst O2 did not sell, Vodafone would gain 10 (i.e. 120 – 110 = 10) today. However, if O2 retaliated in the following period by selling a block of spectrum, Vodafone would lose 35 (this is given by the difference between the 110 that it would earn in the collusive equilibrium and the 75 that it would earn after both incumbents have sold) in each following period. It is clear that this punishment would suffice to deter

[24] Note that for this prisoner's dilemma situation to arise, each player would find it attractive to sell if the other did not, although in the end both players are worse off by selling, compared to a situation in which neither sold.

Vodafone from selling today. Furthermore, O2's threat to punish Vodafone after Vodafone has sold is credible, since once Vodafone has sold O2 is better off by also selling over not selling (because its profits would be 75 instead of 50).

It is therefore possible to generate an example in which the outcome envisioned by Ofcom could arise. However the existence of an example, does not support the position that *"Ofcom considers that a plausible outcome of the strategic interaction between the 900 MHz operators is for no trades to happen"*. In repeated games of the sort considered, whether or not a collusive outcome can be sustained depends crucially on the assumptions on the players' payoffs. We consider an outcome in which no incumbent selling cannot be sustained because:

- first, the threat of punishment is not sufficiently severe to deter deviations, and
- second, because the threat of punishment is not credible.

Table 31 below presents the first case. Each incumbent has an incentive to sell if it believes that the other incumbent will not sell (because it earns 200 vs. 110).

		O2	
		Don't Sell	**Sell**
Vodafone	**Don't Sell**	110,110	100,200
	Sell	200,100	105,105

Table 31: Non-sustainable collusive outcome: ineffective threat

Furthermore, the loss in profits from increased competition is not that large and therefore the incumbents would not lose much if they both sold relative to the case in which none of them sold (because they would earn 105 compared to 110). This example describes well a case in which the cost savings to third parties from buying 900 MHz spectrum are relatively large and the effects of increased competition on the incumbents' profits are relatively small.

In a situation like the one represented in Table 31, both incumbents sell in a static game and this outcome would not be reversed in a repeated game. The reason is that, although Vodafone's threat to sell if O2 sells is credible (since Vodafone would earn 105 vs. 100), the loss in profits to O2 from this punishment (i.e. 110 -

105 = 5) is not sufficiently severe to offset the gains that O2 would achieve by deviating today (i.e. 200 – 110 = 90). Based on the evidence presented earlier, and the overall case of Vodafone, this is a more realistic set of assumptions, than the set of assumptions that would lead to what Ofcom has called a 'plausible' outcome.

Table 32 below presents the case in which the threat of punishment is effective but it is not credible. In particular, the game represented in Table 32 is the same as the one represented in Table 30, but we now introduce some asymmetry in the incumbent's gains from selling if the other incumbent also sells (i.e. O2 earns 75 from selling when Vodafone also sells, whereas Vodafone earns only 40 when O2 also sells)[25].

		O2	
		Don't Sell	**Sell**
Vodafone	**Don't Sell**	110,110	50,120
	Sell	120,50	40,75

Table 32: Non-sustainable collusive outcome: non-credible threat

In a static game (i.e. when the game is repeated only once), the outcome has one trade occurring, with O2 selling and Vodafone not selling. This is because, in this example, O2 always prefer to sell independently of Vodafone's actions and, given this strategy by O2, Vodafone prefers not to sell. This outcome does not change in a repeated game because Vodafone's threat to sell one additional block of spectrum to a fourth player if O2 sold one block of spectrum to a third player would not be credible - conditional on O2 having sold, Vodafone prefers not to sell (since it earns 40 vs. 50). Since O2 knows that Vodafone will not carry out its threat it follows the most profitable course of action, which is to sell. In this example we would therefore have at least one sell regardless of whether the game considered is static or repeated.

Ofcom recognises that when using a framework of 'repeated games', the sale of additional spectrum may not be an effective threat, and then suggests (paragraph 8.29) that retaliation *"could easily take the form of other*

[25] This would represent a case where the loss of profits from the increase in competitive intensity from the sale of the 2nd block of spectrum would be relatively large, compared to the price that the 2nd acquirer would be prepared to pay for the 2nd block.

decisions such as pricing in downstream markets". There are however a number of actions that operators could take to seek to restrict the intensity of competition, totally unrelated to spectrum trading. If, as Ofcom seems to suggest, this would be a possible outcome in relation to the trading of spectrum, then why is it not a possible outcome in relation to a range of other dimensions which affect the intensity of competition and which can be influenced by the operators? In practice, the evidence in the UK mobile sector supports the opposite conclusion – for example the UK mobile sector has seen extensive entry of MVNOs. Were the sector to be operating as Ofcom is alleging it could, it should have been in the interest of the operators to prevent such entry.

Finally, it is not clear how Ofcom's conclusions in this chapter are consistent with its finding that the UK mobile market is effectively competitive.

In summary, when using the framework of repeated games, the theoretical outcomes depend, amongst other, on the pay-offs to the different parties, the timing of such pay-offs, and the relative weight different parties put to the pay-offs at different points in time. There is no evidence provided in Ofcom's exposition to support the position that repeated interactions between players are likely to lead to the sustainability of a tacitly collusive outcome, where both parties would not sell. We have provided at least one scenario with what would seem to be for Vodafone more realistic assumptions about the pay-offs to the different parties, which would imply that a collusive outcome could not be sustained.

Annex 6: Critique of Ofcom's welfare analysis

Annex 10 of the consultation presents Ofcom's welfare analysis of spectrum release. Specifically, it presents the modelling it has undertaken to assess the relative impact of spectrum release on allocative efficiency and dynamic efficiency, compared to a situation of spectrum liberalisation with no mandated release or roaming requirement (Option A in the consultation). This is then used in Sections 10 and 11 of the consultation to describe the potential benefits from some form of mandatory release of 900 MHz spectrum.

In the remainder of this Annex we set out, for each of Ofcom's models, our understanding of its analysis, our interpretation of the results and what we consider to be the shortcomings in Ofcom's analysis. First we comment more generally on Ofcom's approach to the welfare analysis.

Ofcom's overall approach to the welfare analysis

Ofcom acknowledges, in Annex 10 of the consultation, that accurate quantification of the welfare implications of spectrum release are difficult to make. It therefore states that its analysis should only be viewed as being "illustrative of the order of magnitude of the welfare effects that could arise". Nevertheless, Ofcom then goes on to attempt to quantify the potential impact of spectrum release on both allocative and dynamic efficiency, with these assessments forming a part of Ofcom's justification of its choice of option.

Given the relative prominence that Ofcom places on this analysis, it is important that the limitations of the analysis are properly recognised and all assumptions used in each model fully justified and sourced. Ofcom's assessment of the potential impact of spectrum release on allocative efficiency rests entirely with its choice of model (the Cournot model), whilst its analysis of the potential impact on dynamic efficiency is largely driven by an assumed relationship between competition and take-up of next generation ("4G") mobile services.

Ofcom's analysis of allocative efficiency

Annex 10 describes three ways in which spectrum liberalisation without release might affect allocative efficiency, namely:

- market participants choosing to offer services that differ in their levels of quality, thus affecting the level of competition, to the extent that some consumers value service quality;

- market participants offering services of the same quality but having differing levels of fixed and/or marginal costs; and
- through differences in the level of costs between players resulting in a change in the number of players in the market.

Ofcom concludes that the first two possibilities cannot be modelled effectively. It therefore concentrates its analysis on the third point, namely the impact on welfare of a change in the number of active players in the market.

Ofcom assesses the potential impact on welfare of a reduction in the number of players by applying a basic Cournot model of oligopoly behaviour, assessing equilibrium price and market quantity before and after exit. It then uses (assumed) demand and cost functions to assess the impact of exit on consumer and producer surplus, applying a real social discount rate of 3.5% to estimate the impact on the net present value of welfare (giving equal weight to producer and consumer surplus).

As set out further below, we do not consider that the Cournot model chosen by Ofcom is the most appropriate economic model by which to assess the potential impact on allocative efficiency. In addition, even within the confines of the Cournot model, we believe that Ofcom has failed to demonstrate properly the likelihood of exit occurring or the probable welfare impact of exit.

Interpretation of the model results

Annex 10 presents Ofcom's 'base case' analysis of the welfare implications of exit, together with a range of scenarios showing, for example, how the results change with different assumptions on discount rates and elasticity of demand. Its base case considers the example of one operator exiting the market in 2010-11 and predicts a welfare loss, compared to the counterfactual of no exit, of £1.1 billion in 2007-08 terms. This is, itself, comprised of a £4.9 billion decline in consumer surplus and a £3.8 billion gain in producer surplus from the reduced competition.[26]

However, Ofcom's model of the effect on welfare of potential exit from the mobile market is based on the Cournot oligopoly model. The Cournot model has, by assumption, the outcome that welfare will increase as the number of competing firms in a market increases. Therefore, Ofcom's result that welfare falls as firms

[26] This also assumes an elasticity of demand of -1.0, a real social discount rate of 3.5%, and the real price of substitutes falling by 1% per annum from 2012 onwards. The level of marginal cost is determined endogenously in the model such that equilibrium price and quantity in the 'no exit' version of the model are equal to forecasted values.

exit the market is implicit in the model it has chosen, rather than being the output of its analysis. As a result, interpreting the model results is perhaps less important than fully understanding the reasoning that lies behind Ofcom's choice of modelling framework.

Shortcomings in Ofcom's analysis

In the remainder of this section, we present our response to Ofcom's analysis in two parts:

- firstly, the appropriate model on which to base the analysis; and
- secondly, within the confines of the Cournot model, Ofcom's failure to demonstrate why exit might be expected to occur and its implications on welfare.

The Cournot model

Ofcom provides no discussion of its choice of a Cournot model to assess the potential impact of market exit on welfare – rather it states that it has chosen this model (paragraph A10.12). Yet the choice of model to use to assess the welfare implications of exit is fundamental to the conclusions reached, as there are economic models that have been used in the literature, where exit would have an uncertain impact, and in some cases no impact, on welfare. Absent such discussion and justification, it is not possible to offer a detailed assessment of Ofcom's rationale.

The fundamental assumptions underlying the nature of assumed competition in a Cournot model do make it however highly unsuitable as a way of proxying the nature of competition in mobile markets. In particular, in the Cournot oligopoly model, operators are assumed to make decisions about how much quantity they are going to produce of a homogeneous good, with knowledge of the characteristics of demand, and under the assumption that other operators will do exactly the same. They then 'bring' their quantities to market, and price gets determined on the basis of the sum of quantities 'brought' to market (and the characteristics of market demand). It is very unclear how this process of determination of quantity and price, even as a simplified model, has any relationship with the way in which mobile markets operate. In mobile markets:

- quantity decisions are not fixed in advance,
- operators can and do engage in significant price competition, and
- both the overall capacity installed, and the actual volume of calls that can be supplied, can be varied by operators and is not 'fixed'.

Cournot makes very specific assumptions about the impact of exit as the intensity of competition is axiomatically linked to the number of participants in a way that is not obviously the case in mobile markets. It is worth noting in this respect that there is an extensive body of literature that has been developed to seek to support regulatory policy development in the mobile sector, which to Vodafone's knowledge has never used the Cournot model as a way of proxying the nature of competition in the mobile market.

Shortcomings in Ofcom's modelling

As described above, Ofcom has developed a Cournot oligopoly model to assess the impact on allocative efficiency of exit from the mobile industry. Such a model will, by definition, show a decline in welfare associated with exit. However, even if such a model were appropriate (which, as set out above, we do not consider to be the case), we believe that Ofcom's analysis has three potential shortcomings, all related to its failure to set out properly how spectrum liberalisation without release would be likely to result in exit. These are as follows:

Exit from the market would only ever be likely to occur under the high mobile broadband demand scenario.

Ofcom acknowledges repeatedly in the consultation that the growth in demand for mobile broadband services is uncertain and that it is therefore appropriate to consider a range of scenarios in its cost-benefit analysis. However, despite acknowledging this uncertainty, Ofcom then implicitly applies the high demand scenario to its welfare analysis of allocative efficiency. In the low demand scenario, mobile broadband services develop only slowly and consumers' sensitivity to differences in 3G quality is similar to today. In this case, price, rather than high-quality coverage, is likely to be the key factor in determining an operator's competitiveness. In such a scenario, operators without 900MHz spectrum would be unlikely to incur costs additional to other operators in deploying high-quality 3G networks (indeed, they would be unlikely to deploy such networks), whilst, in fact, those operators with 900MHz spectrum are unlikely to re-farm, preferring instead to use the 900MHz spectrum to continue to provide 2G services. In this case, spectrum liberalisation with no release would give no incremental benefit to the existing 900MHz operators and would not create distortion in the market for 3G services. Even under the medium demand scenario, it is not clear that demand for high-quality 3G services would be sufficient to encourage 900MHz operators to re-farm and other operators to compete on quality. Therefore, without clear exposition of why the high demand scenario is considered most realistic, Ofcom's analysis of the impact of liberalisation on allocative efficiency contained in Annex 10 of the consultation is without foundation.

Notwithstanding the above, Ofcom acknowledges in Chapters 6 and 8 of the consultation (specifically, paragraph 8.49 and 8.50) that, even in the high demand scenario, spectrum liberalisation without release would be unlikely to result in exit from the market.

Ofcom suggests in Annex 10 (paragraph A.10.5.3.) that exit could occur if, "differences in the level of costs between players in the market are particularly large". Ofcom does not specify here whether it is considering fixed or marginal costs in its analysis. However, in Section 8 of the consultation, it acknowledges that a "profit shock" for one or more operators, arising from increases in fixed costs, would be unlikely to result in exit (see paragraphs 8.49 and 8.50 which both conclude Ofcom would not expect an increase in fixed costs to result in exit). As such, there appears to be an inconsistency between Ofcom's analysis in Annex 10 and that in the main part of the consultation.

Ofcom does not suggest what level of increase in costs could potentially lead to an exit event occurring. However, we note that, in the course of previous regulatory inquiries regarding the derivation of regulated mobile termination charges, Ofcom (and the Competition Commission) has acknowledged that cost differences already exist between the 2G operators with and without 900MHz spectrum. These cost differences have clearly not led to exit from the market. Rather, the UK mobile market is considered to be one of the most competitive in the EU (and OECD) and was considered to be competitive even before the entry of the fifth operator. It is therefore not clear why any cost differences for 3G networks would result in exit, when this has not been the case for 2G networks.

Furthermore, we note that linked to the criticism set out above, increases in cost would only be incurred in the event that market demand is such that it is necessary for all players to compete on quality of 3G services and hence incur costs associated with deploying high quality (in building) coverage. This is akin to the high demand scenario, not the low or medium demand scenarios also posited by Ofcom. Whilst Ofcom acknowledges that exit may be unlikely and hence its analysis may present an upper bound of welfare changes, Ofcom has failed to take this point specifically into account when considering the potential welfare loss. In particular, we consider that Ofcom should also have considered the probability of an "exit event" occurring and hence, to get a true estimate of the welfare loss, taken this probability into account in deriving its welfare estimates. Given that the probability of the exit event occurring is substantially less than one this would have the effect of reducing very significantly any estimate of welfare impact of exit.

Notwithstanding the arguments set out above, Ofcom was wrong to consider, in its assessment of the welfare impact of exit, the relevant market as the entire UK mobile market.

Even if an operator was to exit the 'market', it is far from clear that the operator would choose to exit completely the mobile market. Even under the high demand scenario, a number of mobile consumers are

likely to continue to use mobile connections for "2G" services such as voice and SMS, rather than using mobile broadband services. An operator without 900 MHz spectrum will not be at any disadvantage in serving these customers and may therefore be unlikely to withdraw from this part of the overall mobile sector. To the extent that an "exit event" could occur, this might be focused on exit from the market for advanced mobile data/broadband services. It is clearly not appropriate to estimate the impact of this "exit event" with reference to the total number of UK mobile connections and total mobile ARPU. Rather, such an analysis should (subject to the caveats set out above) only consider the market for mobile broadband services.

Ofcom's analysis of dynamic efficiency

Ofcom has also developed a model to attempt to quantify the dynamic efficiency effects of changes in the level of competition. This model is based on the premise that in less competitive markets, firms may have less incentive to innovate, ultimately resulting in delayed innovation in relatively less competitive markets. Ofcom formalises this model by assuming a one-year delay in innovation, expressed as the launch of hypothetical 4G services (the base case model assumes such services are launched in 2014-15, whilst the 'delay scenario' assumes these services will launch in 2015-16). Ofcom then assumes that the level of competition affects only the timing of take-up of new services, not steady state penetration. The model respectively calculates the welfare impact of this catch up occurring over a 3, 5 and 7 year period.

Ofcom further assumes that each successive innovation in the market (such as the launch of 4G services) creates between 10% and 50% incremental economic value (taking into account both producer and consumer surplus). In order to isolate the impact on consumer welfare, producer surplus is assumed to be a fixed percentage of total economic value. Ofcom then uses this framework to determine the possible welfare loss arising from a delay in innovation.

Using the framework described above, Ofcom estimates, for a central case, that a one year delay in innovation could result in a total welfare loss of around £570 million (in 2007-08 terms), with consumer surplus falling by as much as £540 million. This welfare loss would increase the greater the assumed uplift in economic value from innovation, the longer the catch-up period and the faster the assumed adoption profile.

Taking into account the full range of scenarios shows a possible reduction in economic welfare (in 2007-08 prices) ranging from £100 million to £1.5 billion.[27]

Ofcom has, itself, demonstrated that its assessment of any potential losses associated with reductions in dynamic efficiency is highly dependent on the assumptions included in the calculation. Furthermore, the input parameters included in the model are all highly speculative with a high possible margin for error. As Ofcom itself acknowledges, significant uncertainty exists over what "4G" services will entail. As such, it appears that Ofcom's analysis is no more than speculation, with no evidence to support the case put forward, compared to possible alternatives.

Ofcom's analysis on dynamic efficiency suffers also from the same shortcomings as those highlighted above for the analysis on allocative efficiency. In particular, Ofcom has failed to demonstrate that, in anything other than the high demand scenario, mobile operators without access to 900MHz spectrum will be sufficiently compromised as to reduce the efficiency of competition in the mobile sector.

Ofcom's analysis is based on the assumption that a reduction in the level of competition will cause a one-year delay in the introduction of 4G services. It does not state what scale of reduction in competition is necessary for this assumption to hold, but instead concludes this is a, *"conservative judgement, based on the observation that 3G networks have been rolled out earlier in European countries where there were more 3G players"* (paragraph A.10.37).[28] Ofcom quotes the examples of Germany, Italy and the UK (relatively early roll out of 3G) and contrasts this with France (relatively later deployment of 3G).

The roll out of 3G services is dependent on a number of factors and, without proper analysis, it is not possible to link the timing of rollout to the number of operators in a market. For example, the rollout of 3G services in Ireland took place before many European markets. We note, however, that ComReg, in 2003-04, did not consider the mobile (access and origination) market in Ireland to be effectively competitive. A number of other factors also affect 3G rollout, over which operators have no – or limited – control. These, for example, include the timing of spectrum award, the relative costs and physical ease of deploying 3G networks and customer/cultural demand for 3G services.

[27] Ofcom's central case assumes 25% uplift in welfare from each successive innovation, a 5 year catch-up period, medium technology adoption profile, welfare per user estimates based on the Europe Economics (2006) analysis, and a real social discount rate of 3.5%.

[28] We note that Oftel, for example, had found the UK mobile market to be effectively competitive before the entry of the fifth network operator.

Given the above, Ofcom's assumption that links the number of operators to the timing of innovation, is not appropriately supported by evidence.

Furthermore, Ofcom provides no evidence to support its assumptions of catch-up: that where innovation is "delayed", markets can take as long as 5-7 years to catch up.

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