Issue 2

BT's response to:

"Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6GHz spectrum and related issues"

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CONTENTS

Executive Summary 4

1 Introduction 5

2 Overview of BT views on the consultation proposals 5

2.1 Summary of BT's position 5

2.2 Our views on the competition assessment 5

2.3 Our views on the auction proposals 6

3 Answers to the consultation questions 8

ANNEXES :

Annex A – BT alternative auction design proposal for low power licences

Annex B – Rural coverage at 800MHz

Annex C – Low power 2.6GHz licence technical conditions

BT's response to "Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6GHz spectrum and related issues"

Executive Summary

1. BT supports Ofcom's efforts to award the 800 / 2600 MHz spectrum bands (and possibly 1800MHz spectrum) as soon as possible. BT believes it is essential to do this in a way that encourages competition and new entry in order that it will bring benefits to UK citizens and consumers.

2. Ofcom has founded its proposals on the findings of its competition assessment and has chosen to address future competition concerns in relation to provision of 4G mobile broadband by seeking to impose structural measures to create an auction outcome where there are four national wholesale competitors. Ofcom prefers this solution rather than an alternative of introducing behavioural remedies such as regulated wholesale access requirements in the licences. BT is doubtful as to whether this approach will be sufficient, not least because such an outcome cannot be guaranteed. We therefore believe that as a minimum Ofcom needs to be clear as to how it will respond in the event that the auction does not result in four national wholesalers, further reduces post auction or does not develop as anticipated in the future. This suggests that a reserve licence condition, or, at the very least, a clear statement of how Ofcom will respond if concerns arise, is required.

3. BT welcomes Ofcom's proposal to make available a number of low power licences that would share spectrum at 2.6GHz: this would enable much wider participation in the UK mobile market and should facilitate additional innovation and competition to the benefit of UK consumers. Spectrum should be reserved for this low power use with priority given to new entrants and sufficient bandwidth should be available to deliver the services that customers will require. Our preference is therefore Ofcom's proposed "Option 5 – Reserve 2x20MHz exclusively for low-power shared use" for the 2.6GHz low power packaging. We do however have some concerns over the exact technical conditions and the format of the auction for these licences and have provided our own suggestions as to how these may best be addressed.

4. We have concerns over the specification of the proposed 800MHz licence with coverage obligations on both technical and policy grounds and we believe that this is an area where Ofcom needs to amend its proposals and to re-examine the options in the context of BDUK activities.

BT's response to "Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6GHz spectrum and related issues"

1 Introduction

BT is pleased to submit this response to Ofcom's mobile competition assessment and proposals for the award of the 800/2600MHz bands. In our view a successful auction must be designed to foster competition and promote innovation and new entry as this will generate benefits to consumers. Therefore we note the close linkage between the forward looking competition assessment and the auction design. This auction represents a unique opportunity to shape and enable the future competitive landscape for provision of high speed mobile services based on 4G technologies and BT will play its part in making sure that the UK is able to play a leading role in the provision of new high speed mobile services.

In section 2 we provide a brief summary of BT's position on the matters within the scope of the consultation paper and highlight our key points in relation to both the competition assessment and the spectrum auction proposals.

In section 3 we have provided answers to the specific questions that Ofcom has posed.

Finally, we have provided a number of annexes containing more detailed information that may assist Ofcom in understanding BT's positions and views.

2 Overview of BT views on the consultation proposals

2.1 Summary of BT's position

BT supports the award of this spectrum at the earliest opportunity and we are in agreement with many aspects of Ofcom's proposals. In particular we welcome the features of the proposals that may promote greater innovation and will enable wider participation in the UK mobile market, to the benefit of consumers. The competition assessment has rightly informed key elements of the auction design and we agree that it is necessary to address future competition both at the national wholesale level and the sub-national level. We elaborate further in section 2.2 below and in our reply to Questions 5.1 – 5.7.

We welcome the inclusion of the 2.6GHz low power licence proposals within the design of the award. Provided the packaging, technical conditions and auction design are appropriately defined and spectrum reserved for this purpose, these will enable much wider participation in the UK mobile market via small cell sub-national networks with potential to encourage additional innovation and competition in the provision of services to the benefit of consumers.

2.2 Our views on the competition assessment

BT agrees that it is essential to include specific measures to promote competition and notes the determination with which Ofcom defends the need for there to be four national wholesale operators. Ofcom seeks to achieve this outcome by the use of minimum spectrum floor packages. BT's preference would be that Ofcom removes the spectrum floors and instead promotes competition by putting a regulated wholesale access condition in the new licences.

In any event the auction design does not guarantee an outcome of four national wholesale competitors nor do Ofcom's arguments in support of this objective provide any certainty that this would, in itself, be *sufficient* to ensure that those operators would offer wholesale access on fair and reasonable terms.

We believe there is a strong case to require that action is taken to ensure regulated wholesale access rights to national networks in the event that four national wholesale network operators do not emerge from the auction, that the number further reduces post auction or that their behaviour does not support competition as Ofcom anticipate in the future. As a minimum we believe a reserve condition should be included in the high power licences which would be triggered if this were the outcome. BT is happy to work with Ofcom to determine the appropriate structure such an obligation should take. Ofcom's focus on structural measures is important but this should be associated with behavioural measures to incentivise the appropriate behaviour.

Ofcom should not underestimate the negative effect that an absence of associated behavioural measures would have on potential new entrants. In particular, the uncertainty over whether a suitable wholesale access agreement can be secured to enable national roaming for customers of low power licensees represents a significant risk to new entrants seeking to value that low power spectrum. This material uncertainty, together with the fact that Ofcom's preferred proposal is not to reserve spectrum for new sub-national networks, is in marked contrast to the proposals to guarantee that four national wholesale competitors can hold sufficient spectrum to operate national networks. If guarantees for the incumbents are appropriate then some guarantees for new entrants are equally appropriate. It will be important to address and resolve this issue in the final proposals, otherwise the additional benefits to consumers that additional new entry, innovation and competition would provide is unlikely to be realised, contrary to Ofcom's aims.

Noting that the spectrum caps are intended to apply only until the conclusion of the auction, we are in agreement with the proposed spectrum trading conditions, including the provision for Ofcom to conduct a competition assessment before consenting to any trades. It will certainly be necessary for Ofcom to ensure that a sufficiently competitive market structure develops and is maintained in the future given the emphasis that Ofcom has rightly placed on this issue in the current competition assessment.

2.3 Our views on the auction proposals

BT welcomes Ofcom's proposal to accommodate low power 2.6GHz shared use of spectrum that could support a much wider participation in the mobile market in the form of small cell operators. The availability of wholesale access to national networks for national roaming will be an important aspect of such propositions and it is important that this aspect is addressed in Ofcom's overall plans. This availability of low power spectrum will enable new competition and innovation and will benefit UK consumers. However there are some additional important aspects of the proposals that require further attention, notably:

- The shared low power spectrum should be a block of **2x20MHz** (to enable the fastest broadband services to be provided and interference between multiple licensees to be more easily managed).
- The technical licence conditions need to be further examined to ensure that they are optimally defined. We will present our suggestions for technical conditions that we believe to be more appropriate and will also engage in Ofcom's planned further consultation on this issue.
- To allow practical application outdoors, the number of low power licences needs to be reduced in outdoor environments. We propose an alternative packaging structure that provides for

different numbers of low power shared licences in indoor and outdoor environments (see response to Question 9.1 and Annex A).

- The availability of shared low power spectrum should be guaranteed and not conditional on there being no higher value bid by a single operator to use the spectrum for high power use. We propose that 2x20MHz of spectrum is **reserved** for low power use. Furthermore, with a reduced number of licences there is a significant risk of market foreclosure by national wholesale operators. Therefore we also propose that the 2x20MHz of spectrum is **reserved** for new sub-national network competitors.

Ofcom should not to seek to simplify the auction at the expense of risking an inefficient auction, or an outcome that results in additional complexity later on when the licences are put into use. The changes that we have proposed for the low power licence award need not substantially increase the complexity of the award and are considered by BT to be important to ensure that the spectrum can be used to greatest benefit in an efficient and simple manner.

BT does not consider that the proposed 800MHz rural coverage obligation is appropriately specified. The consultation proposal will be technically problematic to achieve (and verify), certainly with any significant take up in service (rather than considering theoretical service capability in an unloaded network). The proposal also raises some concerns in relation to policy, in terms of how broadband coverage is procured and best delivered. The structure of the licence with rural coverage obligations is, in effect, a public subsidy for rural broadband delivery which has an anti-competitive effect on other rural broadband technologies and which would be delivered more appropriately via an open procurement process. The coverage target specified would, in any event, arguably offer less than the current fixed network can deliver (with WiFi providing in-home mobile coverage).

Separately, we have noted that the auction outcome will be used as the proxy for calculating the fees which will apply to spectrum already in mobile use, i.e. the 900MHz and 1800MHz spectrum and ultimately have potential impact on the full administrative pricing of the 2100MHz 3G spectrum at the end of the initial licence period in 2021.The outcome of this current exercise then will set the framework for mobile spectrum charging for the foreseeable future and as such any inadvertent distortions imposed at this stage will have long term negative impact. A key requirement therefore is comparability between the spectrum being auctioned and spectrum whose charging it will influence. In our view a package bearing a separate and specific set of obligations, such as a rural package, would not have the necessary common characteristics and thus the price of such a package should be excluded from the calculation of any subsequent Full Market Value. Ofcom therefore needs to consider very carefully the reference points it chooses for setting future licence fees, to avoid either undue advantage or disadvantage to those licensees affected.

Finally, BT notes that Ofcom plans to issue two further consultations covering (i) interference issues between 800MHz mobile systems and Digital Television, and (ii) the technical licence conditions that will apply to the 800MHz and 2.6GHz licences. Depending on the detail of these proposals, it may be necessary to revise our position on some aspects of the present consultation (e.g. the number of low power licences). It is unfortunate that these documents could not be made available prior to the close of the present consultation so that respondents could take full account of all the relevant factors in making their comments. We would therefore ask that Ofcom considers any revised views on the present proposals that may be submitted as part of responses to those later consultation papers.

3 Answers to the consultation questions

Mobile spectrum bands

Question 4.1: What use, if any, would you make of the top 2x10 MHz of the 800 MHz band in the second half of 2012 if it were available for use? What would be the benefits for citizen and consumers of such availability?

Taking into account the expected timing of the spectrum auction (in Q1 2012) and the further time that would be needed to deploy a network, it seems unlikely that if BT were to bid for and win the top 2x10MHz of 800MHz spectrum we would make significant use of the spectrum prior to end of 2012. Earlier access to the spectrum would therefore be of limited benefit to consumers.

Question 4.2: If we were to offer shared access low-power licences in some way, do you have any comments on the appropriate technical licence conditions which would apply for the different options?

General

BT welcomes the inclusion of low-power licences within the award proposals and agrees that these would promote increased innovation and competition. Their inclusion would bring greater benefits to consumers than the alternative of simply awarding exclusive high power licences for the entirety of the available spectrum. The availability of multiple shared low power licences will allow wider participation in the mobile market in terms of the number of operators that can be supported and the use for small cells will enable a highly efficient use of spectrum which will benefit consumers in terms of the services delivered, compared to the alternative of just one operator using the spectrum for high power. The sub-national low power network operators would need to have confidence that wholesale access to national networks will be available for national roaming.

The dramatic increase in data traffic forecast by industry analysts leads BT to believe that the number of indoor licences should be maximised as there is a clear mobile industry trend towards smaller cells to deliver the capacity that consumers will demand. Use of small cells represents a highly efficient use of the spectrum because of the greater capacity that can be provided with the intensive frequency re-use that can be achieved across a given area. Further, with on-going improvements in backhaul (broadband lines), there is the possibility that the radio interface rather than the fixed network will become the key determinant of service throughput.

The overall network capacity is significantly improved with indoor small cells. In order to maximise the number of licences it is important to get the technical conditions right, otherwise interference problems will lead to poor user experience and the efficiency of the spectrum use will decrease. BT believes that it is important that the technical conditions are appropriate to the number of licences and the nature of use of these licences.

Ideally the auction mechanism should allow the market to decide on the optimum number of shared licences and the use to which these will be put (indoor only, or outdoor and indoor) so that the value of benefits to consumers can be maximised. We have outlined an auction design that could achieve this (see our answer to question 9.1 and Annex A). However, if auction complexity is a major concern then we believe that appropriate definition of indoor licences and a reduced number of licences usable in outdoor environments will allow the majority of benefits to be captured.

Preferred award option

BT considers that availability of a full 2 x 20 MHz of spectrum for low-power licensed use is necessary and appropriate. 2 x 20 MHz will enable the radio system to take full benefit from the high backhaul

speeds increasingly available and will provide the greatest ability to manage interference between users, ensuring that the indoor or small cell experience for consumers is not poorer than that experienced on a wide area network. Our clear preference is therefore Option 5 (Reserve 2 x 20 MHz exclusively for low-power shared use) as listed on Page 56 of the Consultation paper.

BT considers that shared use of the same frequencies by low-power and high power systems will be constraining for the low power licensees who may not have other spectrum to fall-back on in situations where interference problems arise. The risks and constraints arising due to interference are increased and the utility of the spectrum for the low power users will be impacted. In the same way that Ofcom wants to ensure that the four national wholesale providers have the best spectrum (e.g. by excluding the bottom two 800MHz lots A1 from the minimum floor packages, as per Table 8.3), competing low power operators should similarly be assured access to suitable spectrum. We therefore believe that Option 5 is the best way forward. However, if Ofcom does not implement Option 5 then Option 6 (2x10MHz shared high power and low power, plus 10MHz exclusive low power) is the next best alternative, but is much less attractive because of the added uncertainties for both the high power and low power licensees as explained above.

Other options with just 2 x 10 MHz for low power use - Option 2 (competing with high power use) and Option 4 (reserved) - are much less useful than Options 5 and 6. As mentioned above, 2 x 10MHz will risk negating the benefits that high-speed backhaul would bring, will make interference management between licensees more difficult to manage and, counter productively, may lead to poorer quality services for consumers using low power networks indoors than those reliant on high power outdoor networks that may have wider bandwidths available.

More generally with regard to options 2 and 3, we see that competing with high power users has potential to compromise the introduction of low power users due to competition within the auction and the free rider risks created by the auction design (see our response to Question 9.1). Therefore we not advocate either of options 2 or 3.

Option 1 (no low power licences) is not supported by BT as this will not encourage innovation and competition and will consequently be detrimental to the interests of consumers.

Technical considerations
BT has analysed the technical and operational aspects of the proposed 2.6GHz low power licences in four important areas:

- The maximum number of licensees; Ofcom proposes up to 10.
- The maximum transmission power permitted; Ofcom proposes 1W (30dBm) EIRP for all environments.
- Co-ordination condition among licensees; Ofcom proposes (through the Real Wireless report) maximum height of 10-12m with no other mandated requirements.
- The viability of the coexistence of high and low power users sharing the same frequency; Ofcom has proposed this in one configuration option (Option 6).

In carrying out this analysis BT has made a number of assumptions as follows:

Due to propagation characteristics and power requirements, we believe it is necessary to divide the environment into two categories in which low power licensees can operate

- *Indoor* is defined as a 'residential indoor environment'.

- *Outdoor* is defined as 'public, enterprise and external environment'.

We assume the low power small cell operation modes as follows:

- Indoor small cells operate with only a limited number of network subscribers (e.g. family members) able to use the small cell.
- Outdoor small cells (including cells located indoors but designed to extend to cover outdoors) operate on a 'open' basis similar to that of the macro network where subscribers of the same operator will be able to access the operator's small cell
- There is no roaming enabled between different low power operators' networks (whether indoor or outdoor).

In Annex C we provide more detailed discussions and analysis of the above issues. Our interference analysis suggests that both coverage and capacity have a highly non-linear relationship with the number of licensed operators. In the scenario where the number of licensed operators exceeds two, coverage and capacity performance can become severely impacted. With a large number of licensed operators and a high density of femtocells (a likely scenario in dense urban areas such as central London), the shared licence service would not be viable due to interference. This is in contrast with the Low Power GSM (narrow band FDD) situation due to the use of OFDMA wideband based technology (i.e. LTE). With OFDMA fewer licences can be offered whilst retaining an acceptable service level.

BT is concerned that if the number of low power licences is as large as 10, with all having the right to deploy systems outdoors and the ability to use power levels of up to 1W, coexistence between the licensees will be very challenging in locations where multiple networks are deployed. Potentially this could be mitigated by deployment coordination, operating in "Open subscriber group" mode and roaming agreements, however these could be difficult to achieve with so many parties involved. An alternative method such as dividing up the spectrum into 10 narrow bands would require that all operators deployed the same standard, most likely LTE, but all would suffer inefficiency due to the guard-bands required. In addition, the "narrow band" LTE approach reduces the spectrum efficiency and hence overall service level, due to the high LTE management overheads.

The situation differs between 'indoor' and 'outdoor' deployments due to the favourable attenuation of building walls at this frequency and the different operating models. Accordingly it is worth drawing a distinction between these two tiers of operators. For outdoor licences operating on an 'open' basis, BT's recommendation is that the number of licensees be reduced ideally to 3 or at most 5. For indoor licences, the interference level is determined by the deployment density rather than the number of operators and as such a figure of 10 operators should be technically viable.

For outdoor licences, we agree with Ofcom that 30dBm is necessary to achieve a reasonable coverage. For indoor-only licences however the figure of 30dBm is considered unnecessary to achieve residential coverage. A lower figure of 10-20dBm would not only ensure good household coverage but also lower the level of interference enabling a higher density of indoor cells to be deployed without impacting outdoor or macro-cellular networks.
BT sees two main solutions to address our concerns over the technical and practical viability of the present proposals:

Licensing Option 1:

Define two categories of low power lot: D1 indoor very low power, D2 Outdoor/indoor low power with obligations for cooperation between licensees. Ten licences could be awarded as follows:

Lot	Power	Other licence obligations
D1 (Indoor) **7 lots**	10dBm	Code of practice amongst operators to ensure interference mitigation and fair sharing (automated power control, power back off and possibly dynamic scheduling).
D2 (Outdoor/indoor) **3 Lots (reserved for new entrants)**	30dBm	Either mandate the use of the same access technology with roaming agreement among sharing operators, or in case of multiple technologies being deployed, mandated service deployment agreements among sharing operators. Code of practice amongst operators to ensure interference mitigation and fair sharing (automated power control, power back-off and possibly dynamic scheduling). Higher power use may be considered (e.g. with a geolocation database system), by agreement between licensees.

Licensing Option 2:

This would be similar to the above, but modified so that the auction is re-designed to enable bidders to express values for different numbers of shared indoor/outdoor licences (category D2 above), **with the auction determining how many low power licences suited to Indoor/Outdoor use are awarded** (see answer to Q9.1 and Annex C for details of the auction mechanism that could achieve this).

Ensuring that new entrants can acquire sub-national licences

Only new entrants should be eligible to bid for the limited number of available outdoor/indoor low power licences as one of the key purposes of the sub-national licences is to enable additional competition by new players. The national wholesale operators will have sufficient spectrum to deploy small cells if required in the other spectrum available to them.

Other technical licence conditions

We are also of the view that post-auction it may be possible for operators to agree deeper coordination/cooperation arrangements that could enable higher powers to be used without interference in certain locations, for example through the use of a shared geolocation database by operators in order to achieve better coordination. One important advantage of the geolocation database is that it could enable more flexible limits on the maximum EIRP for the outdoor licences, which is desirable in some service provisioning scenarios, like rural environments. Outdoor base stations could register their position and device information with a shared database. Based on this information the database will then instruct the base station on the maximum transmit power it could use within its service area. We note that such database approaches are already being considered by Ofcom in the context of cognitive access to UHF broadcasting bands, and they are also being considered in the work undertaken by Real Wireless. We therefore believe that Ofcom should enable (and certainly not exclude) such future possibilities in the licence conditions.

Other technical aspects

BT has performed an interference study to investigate the extent of adjacent band compatibility problems between radar receivers in the 2.7-2.9 GHz band and mobile networks transmitting in the 2.5-2.69 MHz band. The study has specifically examined whether low power 2.6GHz FDD systems located at the top of the band would be significantly less problematic from an interference and coordination viewpoint than standard high power mobile networks. This work suggests that low power use can mitigate the impact of interference into radars in the 2.7-2.9GHz band that have not been modified to enhance their immunity to adjacent band interference. There may therefore be some benefit in locating low power use at the top of the band to minimise interference problems. The benign nature of the 2.6GHz low power use in respect of interference into radar should enable early deployments and hence earlier potential benefits to consumers than high power networks may be able to deliver.

Finally, we note that Ofcom has indicated that it will consult separately on proposed technical licence conditions for 2.6GHz licences, including low power licences. We will be happy to contribute to that exercise and may include the aforementioned radar sharing study as part of our response to that consultation.

Competition assessment and future mobile markets

Question 5.1: Do you agree that national wholesalers need a reasonable overall portfolio of spectrum to be credible providers of higher quality data services? In particular, do you agree that national wholesalers need some sub-1 GHz in order credibly to be able to offer higher quality data services? Please state the reasons for your views.

BT relies on wholesale supply of mobile network services and expects to do so for a considerable time to come. It is of great importance that there is real competitive pressure within the wholesale mobile network services market. BT recognises that if multiple wholesale competitors are to be supported they do need either to hold sufficient amounts of spectrum in appropriate bands, or have wholesale access to other networks operated by those that do hold the necessary spectrum. As far as we are aware there is unanimous agreement that a mixture of low and high frequency spectrum is optimum to deliver the necessary coverage, quality and capacity that consumers of high speed data services will demand. Sub 1GHz provides better building penetration and therefore deeper in-building coverage at lower costs.

Question 5.2: Do you agree there is a material risk of a significant reduction in the competitive pressures, at least to provide higher quality data services, in retail and wholesale markets without measures in the auction to promote competition? Please state the reasons for your views.

Yes, it is essential to include specific measures to promote competition, both in terms of promoting competing national networks as well as enabling potential new entrants that could bring new innovation and competition, including those based on new sub-national networks. It is in this way that Ofcom's duties set out in sections 3(2) of the Communications and Wireless Telegraphy Acts can be secured.

Since Ofcom's Mobile Sector Assessment in December 2009 the level of competition has reduced following the merger of two national network operators and the industry trend toward continuing network consolidation and sharing. As Ofcom acknowledge in paragraph 5.59 as well as elsewhere, the introduction of new competition at a retail level will be hampered in the absence of sufficiently

intensive competition to provide wholesale access. The auction offers Ofcom the opportunity to strengthen longer term competition and therefore increase choice for consumers.

Ofcom has proposed measures that most likely will assist the two UK MNOs that do not already hold sub 1GHz spectrum to secure new spectrum suitable to build new high speed data networks, potentially reducing the price that must be paid to secure spectrum but with the intended benefit of furthering competition.

As indicated Ofcom's proposal to include measures that may lead to new sub-national networks are welcomed by BT, although it will be necessary to change the proposals in a number of important respects, both the technical licence conditions and the auction rules, if Ofcom's goals are to be realized. Given the critical role the development of such networks could play in the delivery of higher quality data services in both the wholesale and retail markets we believe it is at least as important that Ofcom pays close attention to the availability of equivalent wholesale access of these sub national networks.

Question 5.3: Do you agree there is a risk of potentially beneficial sub-national RAN uses not developing without measures to promote competition? Please state the reasons for your views.

We agree that sub-national RAN infrastructure will be beneficial in terms of innovation that could be enabled and the positive competitive effects that such deployments would bring to consumers.

Measures will be needed to promote and enable such new competition as part of the auction plans given (i) the high barriers to entry in the mobile market (such as access to sites, existing customer base and existing spectrum holdings) and (ii) the possibility that existing players would be likely to factor into their valuation/bids the additional benefit to them if their bid would ensure that new competitors do not secure low-power spectrum that could provide a route for market entry. Furthermore, the national wholesalers may themselves secure high power spectrum below true market value as a result of the spectrum "floors" that Ofcom proposes to use to facilitate the emergence of four national wholesale competitors.

Any new entrants seeking to acquire low power 2.6GHz spectrum for sub-national networks thus begin at a significant disadvantage under the present proposals. Furthermore sub national RAN operators would be bidding at a great disadvantage since they would not know *a priori* that they could secure the suitable wholesale access arrangement for national roaming capability at a reasonable price Therefore, additional measures to promote competition are essential.

Ofcom's proposals in relation to low power 2.6GHz spectrum need to be changed in important respects, most notably the availability of low power spectrum licences should be guaranteed if there is demand from new entrants and not contingent on there being no higher bid (from an existing MNO) to use the spectrum for high power use. Furthermore the arguments which Ofcom itself deploys relating to the need for access to a strong spectrum portfolio to support competition further along the value chain can also be extended to this case.

Question 5.4: Do you agree with the analysis that at least four competitors are necessary to promote competition?

While in our view the arguments presented by Ofcom do not provide a convincing rationale for four players being the optimal we can certainly agree that less than four will mean that competition will be significantly diminished. However, the number of wholesale competitors is not the only issue, it is the scale of the networks and range of technologies and services that are available that determines how credible the player would be as a wholesale partner. This is already apparent in the current market where EE has by far the largest market share and both 2G and 3G networks, in contrast to 3UK. Therefore the possibility that regulated wholesale access conditions may be required needs further consideration by Ofcom, not least because while four competitors may be necessary to promote competition this does not of itself prove that it will be sufficient to do so. There are many different models for competition, and competition could occur at different levels in the value chain with different numbers of players at different levels, therefore undue focus on the creation of a four player regime and structural remedies risks missing the fact that behavioural measures are equally important to promote competition beyond the four main infrastructure providers.

It is worth noting that ensuring four competitors is likely to result in lower spectrum costs for existing players than if the spectrum floors were not introduced. Other players that may be seeking to acquire smaller spectrum packages will not benefit from cheaper spectrum in the same way.

Question 5.5: Do you agree that the specific measures we propose to take to ensure there are at least four holders of such spectrum portfolios are appropriate and proportionate?

Required spectrum portfolios
If Ofcom wants to ensure that four players could build a national high speed data network the proposed spectrum floors (Option 1) could be appropriate, although the amounts ideally required would depend in part on market share.

It appears highly likely that the effect of Ofcom's proposals will be that the existing four MNOs hold or will secure the guaranteed minimum spectrum that Ofcom has identified and that some or all existing players will pay less for spectrum than if the floors were not in place. This is an advantage to the existing MNOs. We would prefer that Ofcom removes the spectrum floors and instead promotes competition by putting a regulated wholesale access condition in the new licences.

We note that one of the floors refers to 2x15MHz of 2.6GHz spectrum which is not an outcome that the auction can deliver and hence we cannot understand why it has been included.

Overall cap on spectrum holdings
BT notes the proposed cap on total spectrum holdings of 2x105MHz (Option 1). This level of cap will have some limited constraints on what some existing players can bid for but is unlikely to improve the likelihood that new entrants can secure spectrum. If Ofcom selects the option of reserving spectrum for low power systems and ensures that there will be sufficient licences to ensure new players secure low power spectrum then BT would support the proposed cap. However, if this is not the case then we would advocate a lower cap in order to assist potential new players in securing spectrum. On the other hand, if low power spectrum is to be reserved for new entrants, then Ofcom could afford to raise the overall cap, as this may allow for the more committed wholesale partners to acquire enough spectrum to provide services in the wholesale market. We assume that the caps will only apply for the duration of the auction. However, it would be helpful if Ofcom makes this clear in its subsequent statement.

Sub 1GHz cap
BT agrees with Ofcom's proposal of 2x27.5 MHz for the sub-1GHz cap (Option 2). It should however be clarified as to exactly which spectrum bands below 1GHz will be taken into account for the floors.

Question 5.6: Given the measures we propose to take to ensure four holders of spectrum portfolios sufficient credibly to provide higher speed data services, do you agree that it would not be appropriate or proportionate to introduce a regulated access condition into the mobile spectrum licences to be awarded in the combined award?

No, we are not confident that reasonable terms for wholesale access will be secured by commercial negotiations alone. As indicated elsewhere in this response, measures to ensure that there are four entities which are able to offer a complete wholesale package, does not by itself lead to such a outcome. Indeed, as Ofcom explains the primary purpose of this policy appears to ensure only that there will be four operators who are guaranteed the ability to operate independently, and it is this strength which will allow competition to develop. It appears to be Ofcom's hope that this will of itself foster more intensive competition between those four and that that will include the desire to provide reasonable wholesale access to others. What is of at least equal significance is whether those operators are incentivised in any way to provide such wholesale services on reasonable terms and conditions, including in particular, to any new entrant.

Ofcom acknowledges that wholesale access on reasonable terms is vital to a vibrant competitive and innovative market and BT would unequivocally agree with this view. Ofcom considers that four operators are optimal on the basis that there is a high incidence of three or four such players in most developed countries, (though in our view this correlation doesn't necessarily imply any such causal relationship). It is of real concern to BT that Ofcom's only response to ensuring that competition remains post auction, is to seek to facilitate the possibility that four national wholesale operators emerge and deliver suitably competitive wholesale access. Based on our analysis of the auction design, while there may be an assumption that an outcome which entails four operators meeting the requirements of Ofcom's definition will be delivered, it is not a given and in practice the auction could begin without any operator declaring itself as a potential national wholesale operator and conclude with less than four operators meeting the spectrum holdings criteria which Ofcom sets out. It is not clear what Ofcom would do in this eventuality to ensure that its duties under the Wireless Telegraphy Act (sections 3(2)(c) and (d) – the desirability of the promotion of innovative services and competition in the provision of electronic communications services) were met.

Therefore BT is strongly of the opinion that Ofcom needs to signal that any diminution to less than four national wholesale operators would of itself trigger some form of remedy or "regulated wholesale access" to a national wholesale operator. We consider that it would be possible to frame appropriate conditions for such a reserve requirement. Given the weight Ofcom attaches to the need for four national wholesale operators we cannot see how the position is credible without such a requirement. It would be appropriate to identify the conditions which could be imposed to contend with different aspects of potential market failure and this would in fact increase regulatory certainty. There is some evidence from the 3G auction that the existence of an explicit regulatory backstop actually helped to incentivise operators to reach a commercially negotiated arrangement
In our view Ofcom's analysis lacks a clear identification of what "good" would look like. Given the barrier to entry which a lack of access to spectrum presents and the costs associated with the development of a national wide area cellular network, it is not enough to solely focus on the structural aspects of the market. It is the quality of those wholesale access agreements which is of equal importance and we believe it is essential for Ofcom to signal its expectations so that there is

regulatory certainty for all players. Of itself this will tend to provide some guidance as to what remedies could be put in place in the event that market expectations are not being met. If Ofcom (notwithstanding the comments above) is not minded to impose a reserve condition at the very least is should indicate a set of market characteristics or thresholds below which a formal post auction review of the market would be triggered.

Reliance on Ofcom's ex post powers to intervene in the market is not sufficient. Any ex post intervention is likely to take time and any undue delay will exacerbate the already challenging market conditions for new entrants. In order to make investments now it is essential that such entrants can be assured that the appropriate regulatory regime exists. This should include measures to secure appropriate terms for wholesale access if they are unable to negotiate those on a purely commercial basis.

The lack of certainty as to what level of wholesale access might be negotiated and particularly under what terms including price will pose a significant disincentive to invest, especially for new entrants and bidders interested in a sub national solution. This higher level of commercial risk, along with the fact that the proposed low power licences suitable for sub-national RANs may only be available if valued higher than a bid for high power use (e.g. by an existing MNO) will deter potential new entrants from participating in the award in our view and will certainly reduce the valuation of the spectrum, and thus will hamper the development of new competition downstream. Ofcom itself acknowledges that this outcome could specifically be orchestrated by bidders intending to reduce potential competition to a minimum level. (See Paragraph 5.25)

Question 5.7: Do you consider that we should take measures to design the auction to assist low-power shared use of 2.6 GHz? If so, what specific measures do you consider we should take?

Yes we agree that measures to assist low power 2.6GHz spectrum usage should be included in the auction as it will promote competition and innovation to the benefit of consumers. This spectrum must however be **reserved** for low power use and bidders should not be in contention with high power use. It is insufficient just to enable aggregation of low power bids.

This is because

- MNOs would have an incentive to bid to exclude competition,
- Without reservation, there are strong incentives to free-ride which would prevent low power users from bidding their full potential value. This would disadvantage low power bidders and risk an inefficient spectrum allocation.
- Low power bidders would express private values in the auction that do not necessarily incorporate the additional consumer benefits arising from more effective competition at the sub-national wholesale level
- New entrants will also have no guarantee that they will get wholesale access on reasonable terms to enable national roaming after they have won spectrum and built sub-national networks. Therefore, additional measures to facilitate low power shared usage are essential.

The amount of spectrum reserved for low power usage must be of sufficient quantity. We explain in our response to Q4.2 that **2x20MHz** is appropriate.

We also believe that the sub-national spectrum should be reserved or prioritized for new entrants. National wholesale operators will be guaranteed substantial spectrum holdings that can deliver

services indoors as well as outdoors and can be used for low power use in any case should those licensees desire.

There should be fewer licences at the 1W level with outdoor use allowed (i.e. 2 categories of low power may be appropriate): a small number of 1W licences that can be use outdoors and indoors, and a greater number of even lower power licences intended for indoor use only. Alternatively the market could determine via the auction how many of the 1W licences intended for outdoor and indoor use should be awarded.

See also BT's response to Question 4.2 on the technical aspects and Q9.1 on the auction design aspects.

Mobile coverage and related issues

Question 6.1: Do you have any comments on the proposal to include in one of the 800 MHz licences an obligation to serve by the end of 2017 an area in which 95% of the UK population lives, while providing a sustained downlink speed of 2Mbps with a 90% probability of indoor reception? Do you think there is another way of specifying a coverage obligation that would be preferable?

BT believes that the proposed coverage obligation is inappropriately specified from technical, competition and policy perspectives.

From a technical perspective, we are of the opinion that the proposed coverage obligation could not realistically be delivered with just 2x5MHz of 800 MHz spectrum as Ofcom has proposed, at least in any practical sense where there is any significant take up of service (rather than a hypothetical scenario where there is coverage and the network is lightly used). A network deployment using only this spectrum package would not have the required capacity to meet typical demand levels expected from broadband users unless many tens of thousands of cells were deployed. Provision of reasonable service to consumers would be all the more ineffectual under circumstances where alternative fixed broadband is not available or only the mobile network bearing the coverage obligation is present. Given the large cell count that would be needed to deliver the proposed licence obligation, this calls into question Ofcom's assertion in Para A11.21d of the Consultation that "given the current proposal for the 800 MHz coverage obligation we do not believe that this would lead to very significant differences in the value of the spectrum".

See Annex B for further technical details to support our technical comments above.

BT also notes that the proposed 90% probability of indoor service for 95% population equates to about 85% of homes. This target is less than the c.89% of homes referred to in the Digital Britain report that had 2Mbit/s or faster broadband and is certainly much less than those that are likely to have 2Mbit/s fixed broadband available in 2017. It is unclear to us why Ofcom is seeking to specify a mobile coverage obligation in terms of *indoor* coverage at all: it is the wrong policy goal. In practice it is likely that most of the 95% of population targeted by the mobile licence holder already would have access to fixed broadband (with WiFi for mobile connectivity in the home) and if the intention is to achieve indoor broadband coverage then it should be specified in a technology neutral manner since it may in many cases be more efficiently provided by alternative technologies, e.g. an upgrade to fixed networks in conjunction with WiFi or a low power sub national RAN. Mobile spectrum is essentially for mobile services, and if any rural coverage obligations make sense, then they should focus on outdoor mobile coverage.

The obligation is also a mistake from a competition perspective. An obligation in an 800MHz licence to provide indoor 2Mbit/s coverage in rural areas will put downward pressure on the auction price achievable for that licence. Ofcom itself acknowledges this in Para 6.25 of the consultation paper where it states that "as the licence obligation would be detailed and published before the award bidders would be aware that they were committing themselves to meeting the obligation and take this into account in determining the level of their bids. This is an indirect way of funding."

From a competition perspective, therefore, Ofcom's proposal is, in effect, a public subsidy to the holder of the relevant 800 MHz licence to support broadband delivery to rural homes. The holder will benefit from valuable spectrum holdings of spectrum in urban areas, for which it will have paid a reduced price. This is a cross-subsidy to rural broadband, where the licence holder will have to pay for the costs of coverage. This is an anti-competitive subsidy against other rural broadband technologies, in particular fixed broadband.

In our view, it would be fairer, more pro-competitive and more logical for any rural broadband requirement to be funded through a transparent and structured process, such as that already in process through BDUK, including the requirement for wholesale access (as would be required under EU law for a government subsidised infrastructure). We suggest that a different approach may be preferred where in areas that operators do not undertake to roll-out network coverage. It may be more appropriate for such rural coverage to be secured via an open broadband procurement process in partnership with BDUK.

This proposal would remove the need for indoor mobile broadband coverage obligations to be specified by Ofcom as part of the 800 MHz auction process, thus avoiding the possibly intractable difficulties of doing so.

In the event Ofcom decides to pursue its original proposal of a coverage obligation in an 800MHz license, BT believes this must be properly defined in a manner that is both technically achievable and economically viable. This would certainly require more than 2x5MHz of spectrum to be used to provide a viable service.

Our recommendation to Ofcom is a) that the rural coverage obligations should be taken out of the licence in their entirety, and all rural coverage should be handled in a technology neutral fashion by BDUK or b) if Ofcom considers that unacceptable, it should be specified in terms that make technical sense and relate to outdoor mobile data coverage.

Question 6.2: We would welcome views and evidence on the costs and benefits of imposing an additional coverage obligation focussed on particular geographical areas, and if such an obligation were to be imposed what might be the appropriate specification of geographic areas?

As indicated in Annex B, the costs of rural coverage will be affected by the capacity that is demanded, and if a relatively modest amount of spectrum (e.g. 2x5MHz as mentioned by Ofcom) is available a large build out of mobile base stations would be needed to deliver sufficient capacity.

If obligations are introduced that require specific areas to be covered by mobile broadband these areas should be addressed in close conjunction with BDUK whose remit is to ensure that these requirements are considered, where appropriate, as part of a technology neutral approach.

We have some experience of the difficulties entailed in seeking to specify geographic coverage. (Specifically in relation to the 2GHz licence we had specifically for rural coverage some years ago) Points which it may be helpful to bear in mind are that costs to different operators may vary considerably dependent upon the network boundaries already built into any existing network they have access to, together with disproportionate maintenance costs of potentially isolated islands of technology. Should Ofcom believe it necessary or helpful to pursue this concept it may be that, at a detailed level, a more efficient outcome could be identified post auction once the host network were known and thus the appropriate geographic boundaries better defined by reference to the host. This could still be built into the auction by nominating the package which would be required to undertake the obligation and setting relevant parameters but without specifying the exact boundaries and giving a range of possible coverage to be achieved both in terms of numbers and speeds.

Question 6.3: Do you have any comments or evidence on whether an additional obligation should be imposed to require coverage on specific roads?

No comments

Question 6.4: Do you have any comments on our proposal not to use the combined award to address existing not-spots?

BT understands that Ofcom is referring specifically to the issue of mobile voice not-spots and existing mobile broadband coverage. On this basis we have no comments.

Question 6.5: Do you have any comments on our proposal not to impose 'use it or sell it' obligations but to consider including an additional power to revoke during the initial term of the licences?

In areas where the national 800MHz operators will not commit to roll-out mobile broadband coverage because it is not commercially viable to do so, BDUK could handle the procurement of broadband coverage and working with Ofcom could optionally make unused 800MHz frequencies available should the winning bidder for a rural broadband project elect to use 800MHz wireless as part of the bid solution. The boundary issues between 800MHz rural use managed by BDUK and licensed national use auctioned by Ofcom would require technical coordination, in a manner similar to the coordination already necessary at international borders of mainland European countries where coordination between networks is routinely undertaken.

Non-technical licence conditions for 800 MHz and 2.6 GHz

Question 7.1: Do you have any comments on the proposals relating to the duration of the initial licence period, our rights to revoke the licence during this period, the charging of licence fees after the end of the initial period and our additional revocation powers following the initial period?

We understand that it is Ofcom's intention to standardise its approach to these matters and agree that this is an important principle, especially as the use of different bands increasingly begin to support competing and substitutional products services and markets.

Question 7.2: Do you have any comments on the proposal to amend the spectrum Trading Regulations to apply to the auctioned licences in the 800 MHz and 2.6 GHz bands, to include a competition check before we consent to a spectrum trade of mobile spectrum and not to allow transfers that would increase the number of 2.6 GHz low-power licensees?

BT agrees with Ofcom's proposals. Indeed BT would suggest that this should be the bare minimum of measures which Ofcom might need to ensure that this spectrum is allowed neither to become too concentrated (without appropriate wholesale access mechanisms being ensured) nor to become inefficiently fragmented.

Question 7.3: We welcome views on the merits of the proposed approach to information provision; in particular concerning the type of information that may be helpful and any impacts that publication of information might have both on licence holders and the wider spectrum market.

In general we agree that publication of the spectrum use information would be useful in order to identify opportunities to trade/share.

Spectrum packaging proposals for the 800 MHz and 2.6 GHz award

Question 8.1: Do you agree with the way in which we are taking account of the main factors relevant to spectrum packaging and why?

Yes

Question 8.2: Are there other factors that we should consider to develop our approach to packaging? If so which ones and why?

We have no other suggestions.

Question 8.3: Do you agree with our packaging proposals for the 800 MHz band? Please give reasons for your answer.

Yes.

Question 8.4: Do you agree with our proposal not to allow relinquishment of 900 MHz spectrum and why? Do you have any other comments regarding our packaging proposals for the 900 MHz band?

BT agrees with Ofcom's proposals not to allow relinquishment. We also agree with Ofcom's proposals for how 900MHz should be packaged if Ofcom did include 900MHz in the award.

Question 8.5: Do you agree with our proposal not to allow relinquishment of 1800 MHz spectrum and why? Do you have any other comments regarding our packaging proposals for the 1800 MHz band?

BT agrees with Ofcom's proposals not to allow relinquishment of 1800MHz spectrum for the reasons that Ofcom has mentioned. We agree with Ofcom's proposals for how 1800MHz would be packaged.

Question 8.6: Do you agree with our proposal not to make provisions to include 2.1 GHz spectrum in this auction and why?

BT has no view on this matter.

Question 8.7: Which aspects of our packaging proposals for the 2.6 GHz band do you agree with and why?

We believe 2x20MHz needs to be available for low power use, not just 2x10MHz. We therefore recommend that Ofcom selects the 2.6GHz low power **Option 5.**

A second best solution would be with half of the 2x20MHz low power spectrum shared with a high power licence and half is reserved exclusively for low power use.

Our reason for seeking 2x20MHz of spectrum for LP uses is so that high bandwidth services may be provided to customers and therefore sub-national wholesalers are able to compete effectively with the national wholesalers, who, we believe, are likely to offer services using 2x20MHz of spectrum wherever possible.

Question 8.8: Do you agree with our proposed approach for eligibility points and why?

Yes we agree with the approach taken to eligibility points, notwithstanding our comments on lot structure discussed under Question 9.1.

Question 8.9: Which approach to reserve prices do you think would be most appropriate to secure optimal spectrum use in the interests of citizens and consumers, and why?

We urge Ofcom to ensure that the reserve prices must not deter new entrants seeking low power spectrum. The low power use would not affect radars so the logic of basing reserve prices for these channels on costs of solving radar interference is weak. We certainly do not agree to reserve prices being set at full market value as Ofcom cannot accurately assess this, and even if they could, it seems unlikely that an auction would be efficient or appropriate.

Adopting different reserve prices per 2 x 10 MHz lot
In auction design it is preferable (absent concerns regarding strategic behaviour) to adopt conservative reserve prices to avoid the risk of auction failure. Ofcom's rationale for high reserve prices is based in part on ensuring that national wholesalers taking advantage of the spectrum reservation at 800 MHz and 2.6 GHz pay market prices for the reserved spectrum. For the LP spectrum (which does not form part of the national wholesale spectrum reservation) we believe that encouraging market entry by sub-national wholesalers is a more important consideration. A low reserve price will encourage participation and market prices to be achieved.

Auction design and rules proposals for the combined award

Question 9.1: Do you agree with our proposals for the auction design and why?

Whilst we believe that the auction format generally is appropriate and should deliver and efficient auction outcome, we do not agree with the auction design with regard to the Low Power (LP) spectrum lot. Our concerns relate to the need for LP licences to compete in aggregate for full power paired use and the number and capability of LP licences. Each of these is discussed in turn.

Competitive allocation between High power and Low power uses
Allocation options 2 and 3 (see page 56 of the consultation document) require the bids for LP spectrum to compete in aggregate with full power paired lots at 2.6GHz. This presents a number of difficulties for potential sub-national wholesalers:

- It allows bidders for full power lots (category C1) to foreclose the opportunity for market entry. Although such bidders may have incentives to free-ride on the anti-competitive actions of others, we note that it only takes the unilateral action of a single full power bidder (to bid for one more lot than they might otherwise have done at final clock prices) to foreclose the market opportunity for new entrants (i.e. tacit collusion between full power bidders is not necessary).
- It raises free-rider risks for LP bidders which would reduce the effectiveness of their bids
- Allocation would be based on private values of low power bidders as expressed in their bids. Efficient allocation of spectrum between full power and LP uses should take account of broader consumer benefits that would arise from competition by sub-national wholesalers which are not necessarily captured in private values.

The free-rider risk is explored in Section 9 of the consultation paper (Paras 9.24 & 9.25) which points out that *"... there is often an incentive for individual small bidders in any ad hoc group that is effectively bidding against a large bidder to be untruthfully by "free-riding" on other members of the coalition..."* and *"In the extreme, this could result in all members of the ad hoc coalition collectively bidding less aggressively than a single, large bidder and therefore not winning the spectrum even if it were efficient for them to do so"*. The consultation document goes on to suggest that this issue is addressed by a second price rule that encourages bidders to bid their full value and a restrictive information policy.

In Ofcom's current proposals, all primary bids submitted are taken into consideration at the end of the supplementary bids round. Many of these primary bids will have a LP lot value that is lower than the bids expressed by other LP bidders in later primary bid rounds. Since there is an overall requirement for LP bids to outbid full power bids in aggregate, the prices paid by later LP bidders will be dictated by the highest (losing) prices bid for full power lots and are therefore likely to be higher than the prices paid by LP bidders who only bid in early primary bid rounds. As long as bidders face different prices for identical spectrum rights they have incentives to reduce their prices and free-ride on the bids of others. The second price rule does little to alleviate free-riding in this case, and therefore there is a high risk of inefficient spectrum allocation.

For these reasons we strongly recommend that spectrum is reserved for LP usage and that Ofcom allocation options 2 and 3 are not adopted.

The nature of the spectrum reservation may have a number of provisions depending on the degree to which Ofcom may wish to encourage market entry by sub-national wholesalers. For an effective reservation, Ofcom must at a minimum remove the requirement to for LP and full power to compete in aggregate for the same spectrum block. This will substantially reduce free-riding incentives in this auction design.

Ofcom should also consider

- de-linking the full power and LP clock prices Where spectrum is fungible between lot categories it is important to link prices so that bidders are able to appreciate the likely allocation in any primary bid round. However, where they do not compete then better value judgements can be made between lot categories when clock prices are set independently.

We strongly believe that the low power spectrum availability should be guaranteed and not be conditional on low power bids exceeding full power bids. Spectrum should be explicitly reserved for low power use. Option 5 (2x20MHz reserved for low licences) is the most appropriate solution in BT's opinion. Option 6 (2x20MHz guaranteed to be made available for low power shared use, but with 2x10MHz of this shared with a high power licensee) could be a second preference if Ofcom is unwilling to reserve 2x20MHz exclusively for low power use, but is not optimum.

Number and capability of LP licences

Currently the Ofcom proposal suggests that up to 10 LP licensees should share the LP designated spectrum. The Real Wireless report concludes on the number of operators *"Overall, we believe that from a technical perspective it is entirely plausible for 7 overlapping low power shared access networks to coexist in a 2x10MHz channel. This increases to 14 for a 2x20MHz channel."* This is based on the assumption that all operators are unlikely to deploy in the same area.

Firstly, as discussed in question 8.7, we believe that the benefits of a 2x20 MHz allocation for LP arise from provision of higher bandwidth access rather than additional capacity as is implicit within the Real Wireless assumption. Therefore it should not be assumed that additional operators may be served due to 2x20MHz being made available.

Secondly, analysis undertaken by BT suggests that whereas 10 operators may be feasible in an indoor environment, the maximum number of operators sharing LP spectrum in the outdoor environment is much fewer if interference is to be managed adequately and cooperation between operators is to be manageable. One reason for this is that LP operators that deploy outdoor infrastructure are likely to deploy in the same areas since these will be perceived to be the most commercially attractive.

Therefore the number of LP licences made available needs to be reduced if there is to be significant value attributed to the LP licences. As a solution to this problem we can suggest two ways forward.

- *Licence option 1* - Create two classes of LP licence, each having distinct conditions regarding areas of use, maximum power and coordination requirements. These can be termed "Indoor LP" and "indoor/outdoor LP" licences (where the indoor/outdoor LP licence allows both indoor and outdoor use). The number of indoor/outdoor LP licences should be limited to 3. The number of Indoor LP licences should be reduced to 7, making 10 licences in total.
- *Licence option 2* - Allow the number of LP licensees to be determined in the auction itself (as in the GSM low power auction). With this approach bids are conditional on the number of sharers that gain access to the spectrum within a range of 3 to 5 bidders.

The first licence option would require the creation of two classes of LP lot. A bidder could bid on either class but not both (since the indoor/outdoor LP class also conveys indoor rights). A difficulty with this approach is that Ofcom must form a judgement on the relative value of Indoor/Outdoor LP and Indoor LP licences to set appropriate clock prices ratios, eligibility weights and reserve prices. If implemented with the requirement for LP to compete with full power, there would remain incentives

for free-riding however by separating the indoor/outdoor and indoor only capabilities the gains from free-riding are reduced. Reserving LP spectrum would simplify these aspects of design substantially.[1]

Licence option 2 allows bidders to submit bids that are conditional on the number of sharers that are granted access to LP spectrum. This potentially allows LP bidders to maximise the overall economic value for the LP spectrum expressed in their bids. If adopted, this approach should be applied for the indoor/outdoor LP licence category where there is greater sensitivity to the number of sharers.

Although we believe that reducing the number of LP licences capable of outdoor operation is essential, it raises a further difficulty with auction design. The purpose of introducing LP licences into the auction is to encourage and facilitate the introduction of sub-national wholesalers. If there are only 4 or less LP licences available then it is in the interests of all incumbent mobile operators to foreclose market entry by bidding for all the LP licences. The shared nature of LP licences would allow them to tacitly collude in this process and achieve this objective at relatively low cost since the burden is shared.

To alleviate this concern, the following bidders should not be permitted to submit bids for LP licences:

- Any bidder that meet the spectrum floor requirements prior to the auction
- Any bidder that declares its intention to be a national wholesaler and therefore compete to enjoy the reservation for 800 MHz and paired 2.6 GHz spectrum.

To avoid posing unfair restriction on those that declare themselves potential national wholesalers but fail to win any of the reserved spectrum, the latter condition could stipulate that the outcome of the auction cannot include scenarios where any bidder meeting the national wholesale requirements after the auction is also a winner of a LP lot.

The low power spectrum award should give priority to new entrants by excluding or limiting the participation of existing national operators in order to promote innovation and competition by new players. If Ofcom were to adopt Licence option 2 the constraint on national wholesalers would only be necessary on the indoor/outdoor LP licence category.

In summary, we specifically propose that the auction format is altered so that either:

(i) Indoor and indoor + outdoor low power lots are separately defined (with different power levels) and auctioned as separate lots.

(ii) Low power bids are conditional on the number of licences (as in the low power GSM auction) and that different technical conditions apply depending on how many licences are awarded.

These two auction formats are described in more detail in Annex A. Our preference is for the former option which we consider to be an appropriate compromise between economic efficiency and limiting auction complexity. With either option, the opportunity to bid for LP licences should be limited to sub-national wholesale operators.

Other aspects not related to LP licences

We have a number of comments on packing in the practical application of spectrum floors within the auction.

[1] With a reservation for LP lots, Indoor LP and Indoor/outdoor LP clocks would be set independently and although the ranking of eligibility weights would be important (i.e. the weight for Indoor/outdoor set higher than Indoor), the precise values are not important. Bidders are not able to bid for more than one LP lot therefore eligibility cannot in any case be transferred from an Indoor LP lots to an Indoor/outdoor lots.

The additional bids submitted in the 1st round by bidders wishing to take advantage of the national wholesale spectrum reservation may not necessarily pack into the available spectrum unless all permutations of spectrum categories are expressed in those bids.

Where potential national wholesalers are confident of winning the reserved national wholesale spectrum (i.e. confident that there will be no market entry), they may bid strategically with bids unlikely to win. Such bids could be used to drive up clock prices and distort price discovery. Withholding the identity of potential national wholesale operators would help in this regard, so that the potential for market entry is uncertain.

We note that there is a case where contiguity cannot be assured in the 800 MHz band: where a bidder wins two lots (A2 and a lot of A4) and another bidder wins two lots (A3 and a lot of A4).

As a final point, we would urge Ofcom not to seek to simplify the auction at the expense of risking an inefficient auction or an outcome that results in additional complexity later on when the licenses are put into use. The changes that we have proposed for the low power licence award ought not substantially increase the complexity of the award and are considered by BT to be important to ensure that the spectrum can be used to greatest benefit in an efficient and simple manner.

Question 9.2: Do you have any comments on the proposed auction rules as explained in section 9, Annex 9 and Annex 10?

See also the response to Q9.1

For the Qualification Stage of the auction the consultation paper makes no mention of any specific measures in relation to the relinquished 2x15MHz of 1800MHz spectrum, if it is included. Given that the EC Decision in relation to the merger of T-Mobile/Orange requires that the purchaser of this spectrum be approved by the Commission and Ofcom, we would seek clarity as to how this will be handled in the auction process.

BT notes that Ofcom intends to use the same or similar bidder association rules for this auction as those used in previous auctions. We agree with this position and would emphasize that early clarity around this point is important to those preparing for possible participation in the award process.

Question 9.3: Do you have any comments on how we should approach the payment of deposits and licence fees?

BT has no comments.

Revising annual licence fees for 900 MHz and 1800 MHz

Question 10.1: Do you have any comments on our proposal to use 800 MHz price information as derived from the auction to estimate the full market value of 900 MHz spectrum?

BT has no alternative proposal and no concern in principle with the approach that Ofcom has proposed. However we would point out that the proposal is unclear as to which three of the four categories of 800MHz lot are proposed to be taken into account in the calculation. Presumably it is the lot with rural coverage obligation that would be the one that Ofcom would exclude as the value of that might partly reflect the costs of covering areas that are not commercially attractive? If instead

it is the Lot A1 in Table 8.31 that Ofcom proposes to exclude, then the rationale is very unclear as to why this is the case (and indeed why Lot A1 is not intended to count towards the minimum spectrum "Floor" packages).

Question 10.2: Do you have any comments on our proposal to use an average of 800 MHz and 2.6 GHz price information as derived from the auction to estimate the full market value of 1800 MHz spectrum?

BT has no alternative proposal to the approach that Ofcom has proposed (but see our comments in section 2.3 above). We do however note that this question has direct bearing on the 2x15MHz of 1800MHz spectrum that might be divested by EE before the auction. Its tradable value prior to the deadline for its divestment will be highly dependent on what annual charges it will attract after the auction (which will be determined by the auction). It is therefore hard to see how it can be sold commercially in advance of the auction without clarity on both the formula that would be used to derive annual charges and without knowledge of the prices that result from the auction. Until at least the formula to be used to set fees is clarified in an Ofcom statement it is hard to see how the spectrum could even begin to be valued buy potential buyers and make a commercial sale in advance of the auction a realistic proposition.

Question 10.3: Do you have any comments on the proposed approach to convert lump sum amounts into annual payment?

BT has no better alternative to suggest and no concern in principle with the approach that Ofcom has proposed.

Annex A – Alternative auction proposals for 2.6GHz low power licences

A1. Introduction

In this section we propose two potential auction designs which are described by their differences to the current auction proposals. Note that both of these auction designs are based on there being a spectrum reservation for low power (LP) users (allocation options 4 to 6).

Both of these auction designs can be applied where LP licences must compete in aggregate to outbid full power paired 2.6 GHz demand, but incentives to free-ride will remain and market entry by sub-national wholesale operators is less likely.

A2. Reserved LP spectrum with Indoor and outdoor LP lot categories

Aspect of auction	Difference from current proposals	Comments
Lot categories	LP lot categories comprise 3 "Indoor/outdoor LP" lots 7 "Indoor LP" lots such that assigned Indoor/outdoor LP lots plus Indoor LP lots is <= 10	**Indoor/outdoor LP lots convey rights for use both indoors and outdoors.**
Clock prices	LP clock prices are independent of the full power paired 2.6 GHz clock price Independent clock prices for Indoor/outdoor LP and Indoor LP licences	**The Indoor/outdoor LP clock price should increase while demand > 3** **The Indoor LP clock price should increase while Indoor/outdoor LP and Indoor LP demand is greater than 10**
Eligibility	Indoor/outdoor LP lots 2 points Indoor LP lots 1 point	**Note that bidders are able to transfer eligibility from other categories to LP lots but are not able to transfer back.** **Similarly bidders are able to transfer eligibility from Indoor/outdoor LP to Indoor LP but not the reverse.** **Hence the ranking of eligibility points is important but the actual values are not critical.**
Activity rule	Each combinatorial bid may only include 1 Indoor/outdoor LP lot OR 1 Indoor LP lot	**As for the current proposals bidders must bid without exceeding the eligibility established in the previous round.**
Bidding caps at the supplementary bid stage	No change	**The relative cap activity rule can be applied as in the current proposals.**
Information provision	At the start of each round, bidders are advised the number of bids received for Indoor/outdoor LP and Indoor LP lots in the previous round	**This is the same principle as embodied in the current proposals**

Winner determination	No change	**Based on all primary and supplementary bids**
Price determination	No change	**All bids are valid and combinatorial**
Assignment stage	**No change**	

A3. Reserved LP spectrum with parallel bidding

Aspect of auction	Difference from current proposals	Comments
Lot categories	LP lot categories comprise: 3 Indoor/outdoor LP lots (based on 3 sharers) 4 Indoor/outdoor LP lots (based on 4 sharers) 5 Indoor/outdoor LP lots (based on 5 sharers) Up to 7 Indoor LP lots such that assigned Indoor/outdoor LP lots plus Indoor LP lots is <= 10	**Indoor/outdoor LP lots convey rights for use both indoors and outdoors.**
Clock prices	LP clock prices are independent of the full power paired 2.6 GHz clock price Independent clock prices for Indoor/outdoor LP and Indoor LP lots Clock prices for Indoor/outdoor LP lots are R/N where R is a reference clock price set by the auctioneer and N is the number of sharers for that lot category	**The Indoor/outdoor LP clock price should increase while there is excess demand in any of the Indoor/outdoor LP lot categories.** **The Indoor LP clock price should increase while Indoor/outdoor LP and Indoor LP demand (for any combination of Indoor and Indoor/outdoor LP categories) is greater than 10**
Eligibility	Indoor/outdoor LP lots (3 sharers) 2 pts Indoor/outdoor LP lots (4 sharers) 2 pts Indoor/outdoor LP lots (5 sharers) 2 pts Indoor LP lots 1 point	**Note that bidders are able to transfer eligibility from other categories to LP lots and between Indoor/outdoor LP lots and Indoor LP lots but are not able to transfer back.**
Activity rule	LP bidders select which of the Indoor/outdoor LP lot categories they would be willing to purchase at the prevailing clock price (note they may make multiple selections) OR	**The eligibility of each combinatorial bid must be less than or equal to the maximum eligibility of any combinatorial bid in the previous round.** **The activity rule is designed to incentivise bidders to bid for all categories of Indoor/outdoor LP**

	1 Indoor LP lot Where multiple Indoor/outdoor LP selections are made each selection forms a separate combinatorial bid that includes other non-LP lots selected in that round. Bidders are not permitted to transfer eligibility between the three Indoor/outdoor LP lot categories.	**lot they would find acceptable at that the prevailing clock price, which is important for price discovery.**
Bidding caps at the supplementary bid stage	Requires change to the relative cap activity rule since there may be more than one bid placed in the "round where the bidder last had eligibility to submit the supplementary bid".	**The relative cap activity rule allows supplementary bid to be increased beyond the price implied by the primary round in which they last had eligibility to submit that bid.** **In this case the permissible increase should be based on any of the bid packages bid for in that round.**
Information provision	At the start of each round, bidders are advised the number of bids received for each Indoor/outdoor LP and Indoor LP lot category in the previous round	**This is the same principle as embodied in the current proposals**
Winner determination	No change	**Based on all primary and supplementary bids**
Price determination	No change	**All bids are valid and combinatorial**
Assignment stage	**No change**	

Annex B: 800MHz licence with coverage obligations

B.1 Summary

In the consultation Ofcom has proposed to include in one of the 800MHz licences an obligation to serve by the end of 2017 an area in which 95% of the UK population lives, while providing a sustained downlink speed of 2Mbps with a 90% probability of indoor reception.

We believe that this coverage obligation could not realistically be delivered with just 2x5MHz of 800 MHz spectrum as Ofcom has suggested. A likely network deployment in this spectrum would not have the required capacity to meet typical demand levels in 2017 from broadband users indoors (unless fixed network broadband with WiFi is also available as an alternative means to provide service to a large proportion of customers). Given there is only one licence with rural coverage obligation it is likely that the licensee will be the only operator in the remote rural areas and thus all the mobile broadband traffic would be on one network which makes the situation all the more challenging.

To evaluate the stated coverage objective along with guaranteed data-rate of 2Mbps, we have conducted a modelling study with results provided in the next section. We note that Ofcom's study has done a similar study on a national basis, here we have focussed on rural areas only, using LTE-FDD technology and 2x5MHz of spectrum in 800MHz band.

The results show a vast number of base stations are required to provide the requested service, even in the 5% of the UK population that fall within the most rural part of the coverage obligation. This is because a practical network has to have sufficient capacity to serve multiple simultaneous users and this increases the base stations count dramatically.

B.2 Technical Detail

This section provides details of the modelling and results. Table 1 provides assumption made for this study.

Table 1: Modelling assumptions

<table>
<tr><td>Scenario</td><td>Sustained downlink speed of not less than 2Mbps in 800MHz with a 90% probability of indoor reception to an area within which at least 95% of the UK population lives</td></tr>
<tr><td>Environment</td><td>Modelled residential indoor environment of 25 sq km for the three traffic profiles[2].
<table>
<tr><th>Geotype</th><th>Min population density</th><th>% of UK population in Geotype</th><th>% of UK area in Geotype</th></tr>
<tr><td>Rural 1</td><td>112</td><td>21.2% (68.8% to 90% of the cumulative %)</td><td>18.4%</td></tr>
<tr><td>Rural 2</td><td>47</td><td>7% (90% to 97%)</td><td>22.1%</td></tr>
<tr><td>Rural 3</td><td>25</td><td>2% (97% to 99%)</td><td>13.0%</td></tr>
</table>
Note that since the obligation is set for 95% of the UK population, Rural 2 is the appropriate geotype for the final 5% of coverage under the proposed obligation.</td></tr>
<tr><td>Carrier frequency</td><td>800MHz</td></tr>
<tr><td>Channel bandwidth</td><td>2x5MHz</td></tr>
<tr><td>Technology</td><td>LTE FDD mode</td></tr>
<tr><td>User location</td><td>Indoors</td></tr>
<tr><td>Radio parameters</td><td>EIRP 63 dBm
Noise figure of 6dB
Receiver implementation margin of 3dB
UE antenna gain 0dB
No of sectors 3
Link layer efficiency 70%
Wall loss 13dB; Body loss 5dB, Standard deviation : Indoor 10dB</td></tr>
<tr><td>Traffic load/data-rate requirement</td><td>On average, to simultaneously receive a guaranteed data-rate of 2.0 Mbps (QPSK ½ AMC scheme)</td></tr>
<tr><td>Interference</td><td>Fixed margin 5dB</td></tr>
<tr><td>Backhaul limit</td><td>No constraint</td></tr>
<tr><td>Percentage of simultaneous users or active users</td><td>Upto 5% of the rural population[3]</td></tr>
</table>

[2] Ofcom mobile call termination report 2010 from Analysys Mason – Distribution of population, area, traffic by Geotype, section 4.1

[3] ICT-KTN positioning paper "Infrastructure analysis and solutions for 800MHz network deployment", section 6 Figure 8
https://ktn.innovateuk.org/c/document_library/get_file?p_l_id=737699&folderId=865485&name=DLFE-32798.pdf

Along with the assumptions stated in Table 1, Table 2 provides calculations about LTE sector capacity of 4.38Mbps and a cell range of 4.8km. Given this achievable range, the system may become uplink-limited unless very low uplink data-rates are assumed. This is downlink only study. The table also provides details of the proportion of users on various modulation and coding schemes[4].

Table 2: LTE sector capacity calculation for a 5MHz channel

Modulation & Coding levels	Effective data rate with 30% link layer overheads (Mb/s)	Required SNR (dB)	Link Budget (dB)	Max Possible Range (km)	Max coverage (sq km)	Fraction of users/data-rate
1/2 QPSK	2.71	5.05	126.94	4.87	47.43	0.61
3/4 QPSK	4.06	10.31	121.68	3.06	18.68	0.03
1/2 16-QAM	5.41	10.83	121.16	2.92	17.04	0.22
3/4 16-QAM	8.12	16.03	115.96	1.84	6.78	0.02
1/2 64-QAM	8.12	16.7	115.29	1.74	6.02	0.07
2/3 64-QAM	10.82	21.29	110.70	1.16	2.67	0.01
3/4 64-QAM	12.17	22.24	109.75	1.06	2.26	0.01
5/6 64-QAM	13.53	23.86	108.13	0.92	1.69	0.04
					Avg. data rate per sector 4.38 Mbps	

B2.1 Study results

Study results are presented in figure 1, where x-axis indicate percentage of the population within the selected rural category (Geotype Rural 1, 2 or 3) who are able, on average to simultaneously receive a guaranteed 2Mbps data-rate, where y-axis shows the number of sites needed in the network to serve the corresponding percentage of population selected in the geotype.

[4] As the user location information is not publicly available, uniform user distribution is assumed for the study.

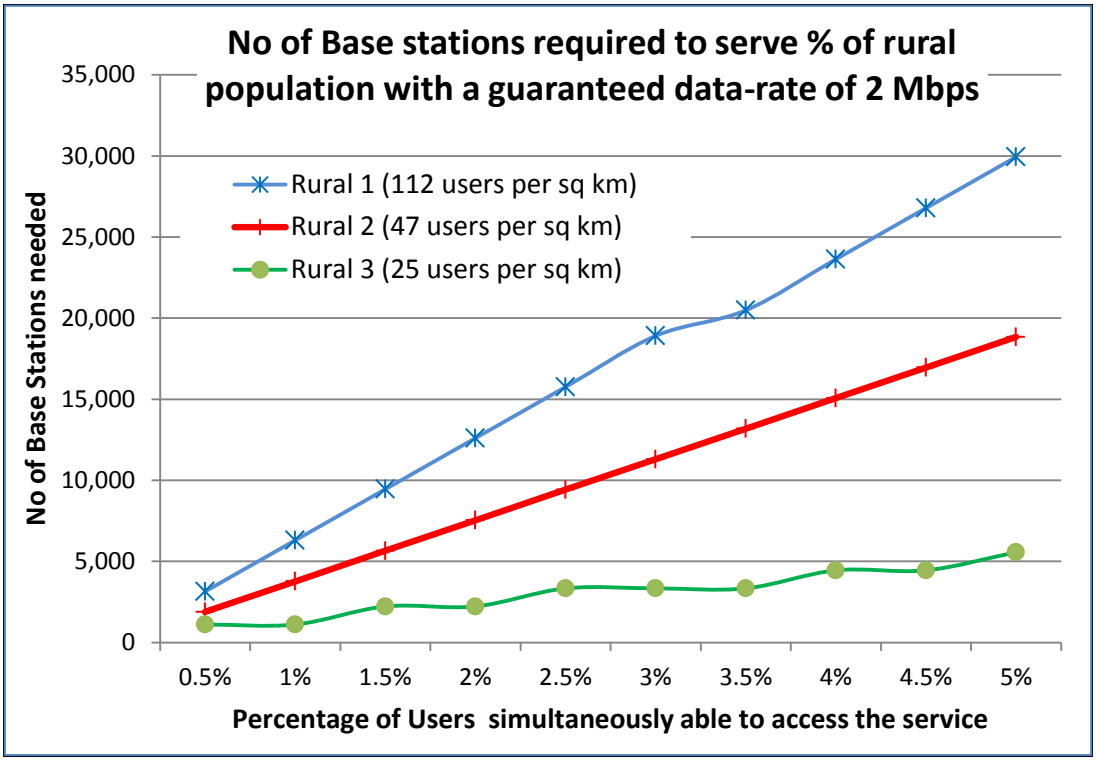


Figure 1: Number of base stations required to serve percentage of population with a guaranteed data-rate of 2 Mbps in rural environments.

Table 3 below provides a summary comparison of base stations needed for all three geotypes with an equivalent range-limited network. We note that the proposed coverage obligation is set for 95% of the UK population, in which case Rural 2 is the appropriate geotype for the final few percent of coverage under the obligation, and Rural 3 is the very sparsely populated areas that are beyond the coverage obligation. For geotype Rural 2, to serve 5% of the Rural 2 population simultaneously with a guaranteed data-rate service of 2Mbps, over 18,000 base stations are required. The high number of base station requirement is driven due to the set criterion of sustained 2Mbps, given the typical sector capacity calculated in Table 2. If serving all users falling within the maximum range of a cell regardless of capacity, the total number of base stations in an equivalent range-limited network scenario for the geotype Rural 2 is about 650. Compared to Ofcom's figure of upto 2%[5], a higher figure of 5% is chosen for the study because in practice the take-up of high speed mobile broadband services is likely to be higher in rural areas where fixed-broadband is less available. The rural areas tend to have the lowest population densities and hence fewer users per cell coverage area which may make the mobile network solution more attractive for serving these areas.

[5] http://stakeholders.ofcom.org.uk/consultations/combined-award/ Annex 7

Table 3: No of base stations required to simultaneously serve 5% of population within the three rural geotypes

Geotype	Guaranteed 2Mbps (capacity limited scenario)	Guaranteed 2Mbps (range limited scenario)
Rural 1	29,943	545
Rural 2	**18,843**	**651**
Rural 3	5,567	385

Overall, the study results show a vast number of base stations are required to provide the guaranteed 2Mbps service, even in the 5% of the UK population that fall within the most rural part of the coverage obligation.

Annex C: System Level Studies of 2.6GHz FDD Low Power Sharing

C.1 Introduction

BT has performed extensive modelling studies of the operational aspects of the low-power shared access to the 2.6 GHz band as proposed by Ofcom. BT's studies are aimed at the system level analysis of throughput and coverage expected in realistic service provisioning scenarios by multiple sharing operators. We believe that these studies complement the study performed by Real Wireless which do not produce a full system analysis for service provision scenarios[6] .

Based on these studies BT have analysed the operational aspects of the proposed 2.6GHz low power licences in three important areas:

- The maximum number of licensees; Ofcom proposes up to 10.
- The maximum transmission power permitted; Ofcom proposes 1W (30dBm) EIRP for all environment.
- Co-ordination condition among licensees; Ofcom proposes (through the Real Wireless report) a maximum deployment height of 10-12m with no other mandated requirements.
- The viability of the coexistence of high and low power operators at the same frequency; Ofcom has proposed this in one configuration option.

From these studies we have drawn a set of conclusions and recommendations. These are summarised below, followed by detailed description of our simulation assumptions, and parameters along with a description of the key findings.

- Our studies indicate that with roaming arrangements and other forms of coordination among operators in place, exclusive low-power concurrent operation in the 2.6 GHz band could provide a service to customers that could be well beyond the level of performance of Wi-Fi, in particular when a high level of service assurance is required at reasonable spectrum cost.
- In the worst-case scenario where all operators wish to provide service in the same area and there is no roaming agreement in place, coverage and capacity performance become severely impacted as a result of sharing, with the average throughput becoming inversely proportional to the number of sharing operators. With a large number of licensed operators and a high density of femtocells (a likely scenario in the dense urban areas such as central London), the environment would not be viable due to inter-operator interference. This problem can, in principle, be solved through roaming arrangement and further coordination between operators. However these could be difficult to achieve with up to 10 parties involved.
- The situation differs between 'indoor' and 'outdoor' deployments due to the attenuation of building walls and the different operating models. Accordingly it is worth drawing a distinction between these two tiers of operators. For outdoor licences operating on an 'open' basis, BT's recommendation is that the number of licensees be reduced ideally to 2 or at

[6] Low-power shared access to spectrum for mobile broadband, Real Wireless, published at http://stakeholders.ofcom.org.uk/binaries/consultation/combined-award/annex/real-wireless-report.pdf, pages 54 and 177.

most 3. For indoor licences operating on a 'closed' basis, the interference level is determined by the deployment density rather than the number of operators and as such a figure of 10 operators should be technically viable.

- For outdoor licenses, we agree with Ofcom that 30dBm (1 W) is necessary to achieve a reasonable coverage. For indoor-only licences however the figure of 30dBm is considered unnecessary to achieve residential coverage. A lower figure of 10-20dBm (10mW-100mW) would not only ensure good household coverage but also lower the level of interference enabling a higher density of indoor cells to be deployed without impacting outdoor or macro-cellular networks.

- The overall network capacity is significantly improved with indoor cells even without roaming agreements in place. If 2x20MHz of dedicated spectrum is not available then BT would favour the 2x20MHz 'hybrid' model and believes this could be operated without excessive impact to the high power licensees.

C2. General assumptions

Due to propagation characteristics and power requirements, we believe it is necessary to divide the environment into two categories in which low power licensees can operate:

- *Indoor* is defined as a 'residential indoor environment'.

- *Outdoor* is defined as 'public, enterprise and external environment'.

We assume the low power small cell operation modes as follows:

- Indoor small cells operate on a '*closed*' basis with only a limited number of network subscribers (e.g. family members) able to use the cell.

- Outdoor small cells operate on a 'open' basis similar to that of the macro network where subscribers of the same operator will be able to access the operator's cell

- There is no roaming enabled between low power operators' indoor and outdoor networks.

C3. Exclusive shared low-power licences

In this study we modelled simultaneous deployment of outdoor low-power femtocells by multiple operators sharing 2x20MHz at 2.6GHz. Simulation studies were performed to investigate the impact of the number of sharing operators on coverage and throughput for the worst-case scenario where there is no roaming agreement and other forms of coordination between operators, and all operators are aiming to provide service in the same area. The environment studied in the simulations is representative of a typical dense-urban area in the UK, with outdoor femtocells are distributed randomly within the service area. User equipment (UE) was distributed randomly at a split ratio of 7:30 between outdoor and indoor. Finally, since no roaming is assumed between operators, each UE can only connect to the closest femtocell belonging to its service provider, with signals from other service providers treated as interference.

Scenario	Multiple Outdoor femtocell operators in close user group mode (no roaming)
Environment	Dense urban areas
Carrier frequency	2.6GHz
Channel bandwidth	2x20MHz

Technology	LTE FDD mode
User location split	Indoor : Outdoor = 70:30
Femtocell density	50, 100, 150, 200/km^2, the density is independent of number of operators randomly distributed but height constraint to below roof top (~10m) as proposed in the consultation document
Propagation model	ITU-P1411 used for street level propagation: Urban, below roof top, street corner at 20m with 80% probability Wall loss 12dB; Body loss 5dB Standard deviation : Outdoor 8dB, Indoor 10dB
Radio parameters	EIRP of 30dBm Device noise figure of 6dB Multiple antenna processing gain of 4.5dB with 2x2 MRC and MIMO Receiver implementation margin of 2dB Antenna gain – 3dB for femtocell and 0dB for UE
Traffic load	Full buffer traffic (worst case)
Interference	Given its closed group operation, UEs can only connect to their service provider. Hence signals from all the other operators are treated as interference.
Minimum modulation	QPSK1/2 with HARQ

Table 1: Simulation parameters and assumptions.

C3.1 Main findings

Figure 1 and Figure 2 show the system level results of the achievable coverage and throughput as a function of the number of sharing operators for three different femtocell deployment densities. As can be seen from these figures both coverage and throughput degrades with the increase in number of sharing operators, and the effects is already very significant even with only two operators sharing. Performance degradation is more gradual in the case of coverage but happens sharply in the case of throughput. Numerical fits to the simulation data reveals that average throughput is inversely proportional to the number of sharing operators while coverage decays much slower.

Further analysis of the above results show that the main reason for the observed degradation in performance is that with closed subscriber groups the femtocell with the highest signal strength at the position of an UE may belong to a different operator than the one with which the UE has a subscription, therefore acting as a strong interference source. This so-called “visitor problem” has been mentioned in the work by Real Wireless as a potential issue but its overall impact on system performance was not analysed. 3GPP suggest that in the case of strong interference, conditional roaming could be used to remedy the problem. The introduction of a roaming agreement between operators would, in principle, eliminate the above capacity and throughput degradation issue, since each UE can connect to the closest available femtocells reducing interference.

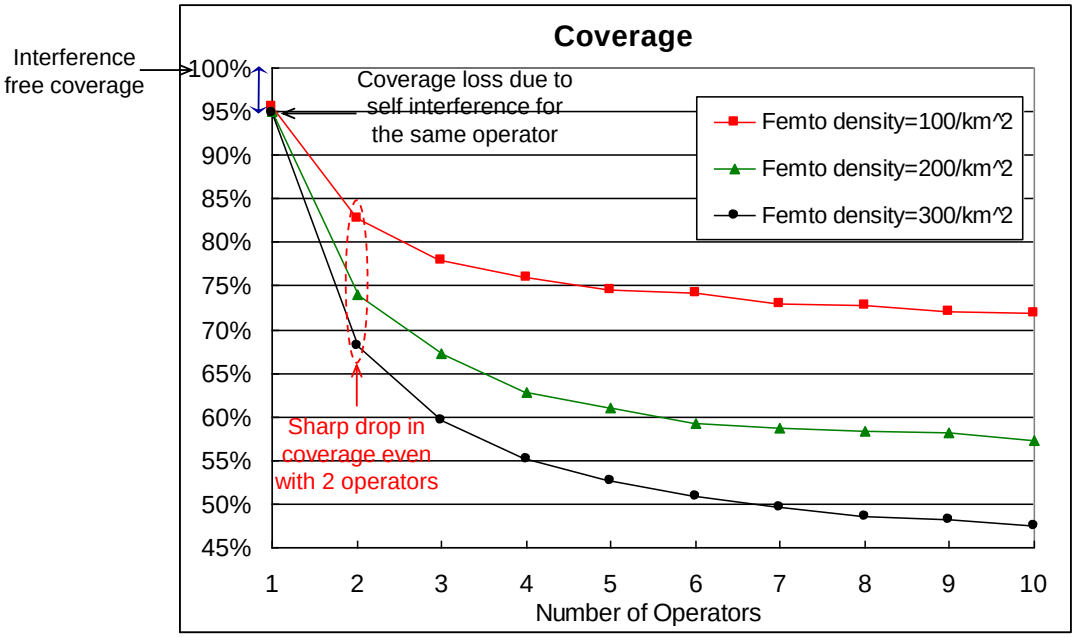


Figure 1: Outdoor femtocell coverage by number of operators

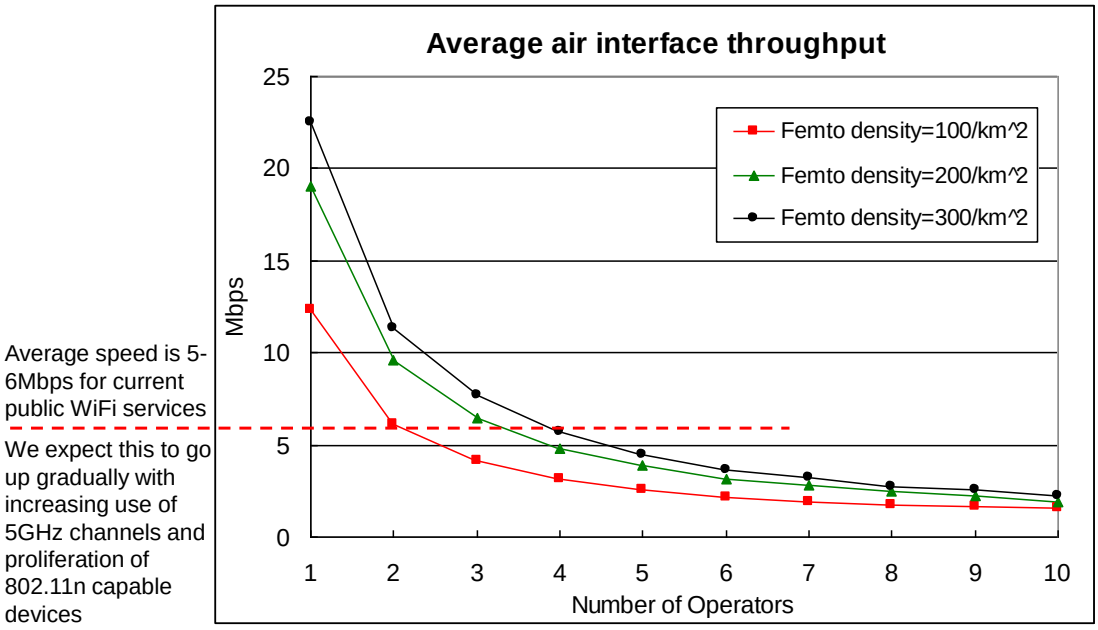


Figure 2: Outdoor femtocell throughput by number of operators.

Focusing on the impact on outdoor cells on the density of indoor femtocells reveals that there is very little sensitivity in either coverage or throughput of the outdoors cells to indoor femtocell density. This is shown in Figure 3 and Figure 4.

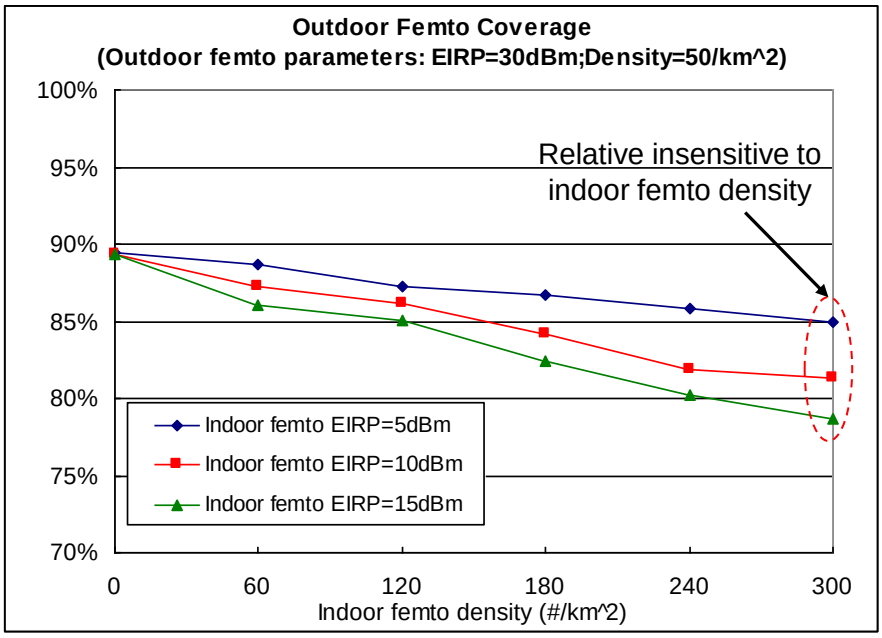


Figure 3: Outdoor femtocell coverage against indoor cell density

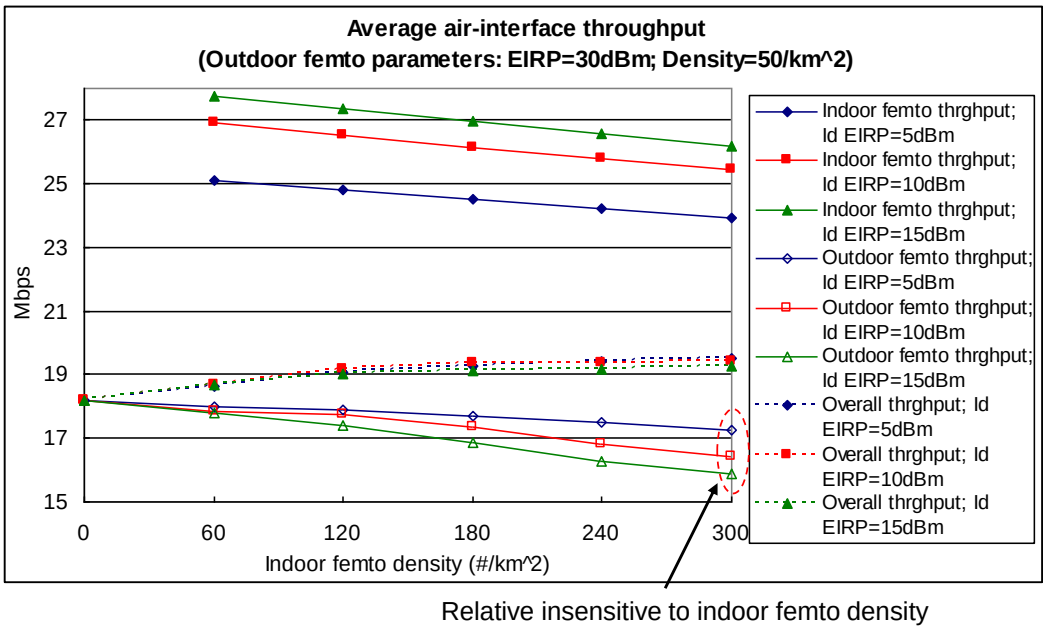


Figure 4: Outdoor femtocell throughput against indoor cell density.

C3.2 Conclusions

- In the worse-case scenario of closed user group mode without roaming agreement or coordination between operators both coverage and capacity drop significantly with the number of concurrently sharing operators, and the effects is already significant even with only two operators sharing. This is due to the fact that the system performance does not degrade linearly with the number of operators.

- Results show that even with just two operators concurrently operating a roaming agreement is essential in order to avoid sharp degradation in coverage and performance. Roaming agreements between 2-3 operators seems feasible. However these could be difficult to

achieve with up to 10 operators. Therefore, we recommend there be only 2 or 3 operators unless viable roaming/coordination solution is can be identified when a large number of operators are sharing.

- Due to wall loss, indoor femtocells do not have much impact on the Outdoor network if a sensible limit of transmit power (e.g. 15dBm) is applied.

C4. Underlay sharing of low-power with high power licences

In this study we modelled deployment of outdoor low-power femtocells which share 2x20MHz at 2.6GHz on an underlay basis with high power macro cells. Simulation studies were carried out to investigate impact this proposed sharing approach on macro cell coverage and throughput, and the required limits on the transmit power of indoor and outdoor femtocells. The environment studied in the simulations is the same as in Section 2.2, with the simulation parameters and assumptions used for the study given in Table 2.

Scenario	Macro and low powered femto (both indoor and Outdoor) shared a single channel
Environment	Dense urban areas
Carrier frequency	2.6GHz
Channel bandwidth	2x10MHz
Technology	LTE FDD mode
Mobile location split	Indoor : Outdoor = 70:30
Femtocell density	Up to 300/km^2. Three indoor and Outdoor ratios are investigated (1, 9:1, 8:2)
Propagation model	Macro: Extended Hata; Macro cell radius of 600metres for indoor coverage Indoor: ITU-1238 Street level: ITU-P1411, street corner at 20m with 80% probability Wall loss 12dB; Body loss 5dB Standard deviation : Outdoor 8dB, Indoor 10dB
Radio parameters	Macro EIRP of 30dBm Device noise figure of 6dB Multiple antenna processing gain of 4.5dB with 2x2 MRC and MIMO Receiver implementation margin of 2dB Antenna gain – 3dB for femto and 0dB for UE
Femtocell traffic load	Outdoor femto: full buffer (worst case) Indoor femto: Monthlylimit/(30days*Usagehour*3600*Max downlink) + Monthlytalktime/(Usagehour*30*60) Where: Monthly limit=2GB, Monthlytalktime=600mins, Usagehour=6
Interference	Macro mobiles can only connect to macro cell. Hence signals from all femto cells are treated as interference.
Minimum modulation	QPSK1/2 with HARQ

Table 2: Simulation parameters and assumptions.

C4.1 Main findings

Figures 5 and 6 both show the impact of combined interference from indoor and outdoor femtocells on macro-cellular coverage. As expected, a lower transmit power, EIRP of 20dBm, rather than 30dBm, has a much less impact on the macro-cellular network. In BT's view 20dBm, or even 10dBm, would be sufficient to provision high quality in home coverage while minimising the impact on the macro-cellular network.

The impact on the macro-cellular network could be further mitigated through interference management techniques such as power control, smart scheduling, automatic power back off and sub-channelization. However, Figure 7 indicates that the net capacity of the network is always greatly increased by the addition of femtocells, regardless of the mix of indoor and outdoor femtocells and transmit power.

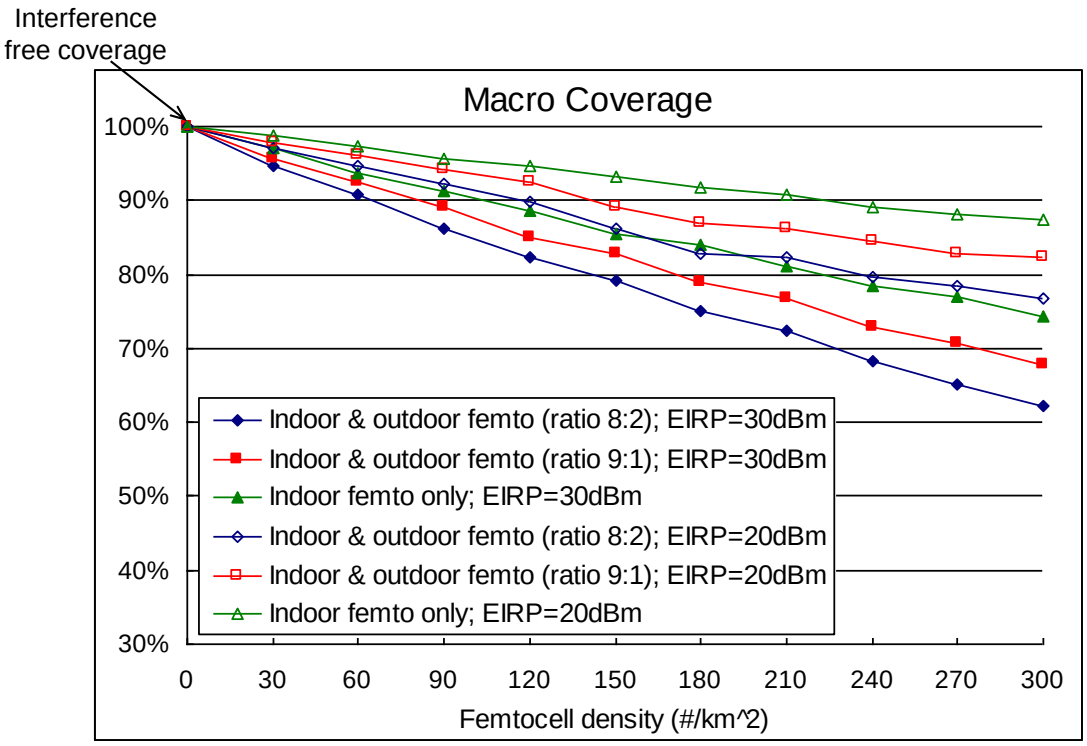


Figure 5: Macro-cellular coverage versus femtocell density

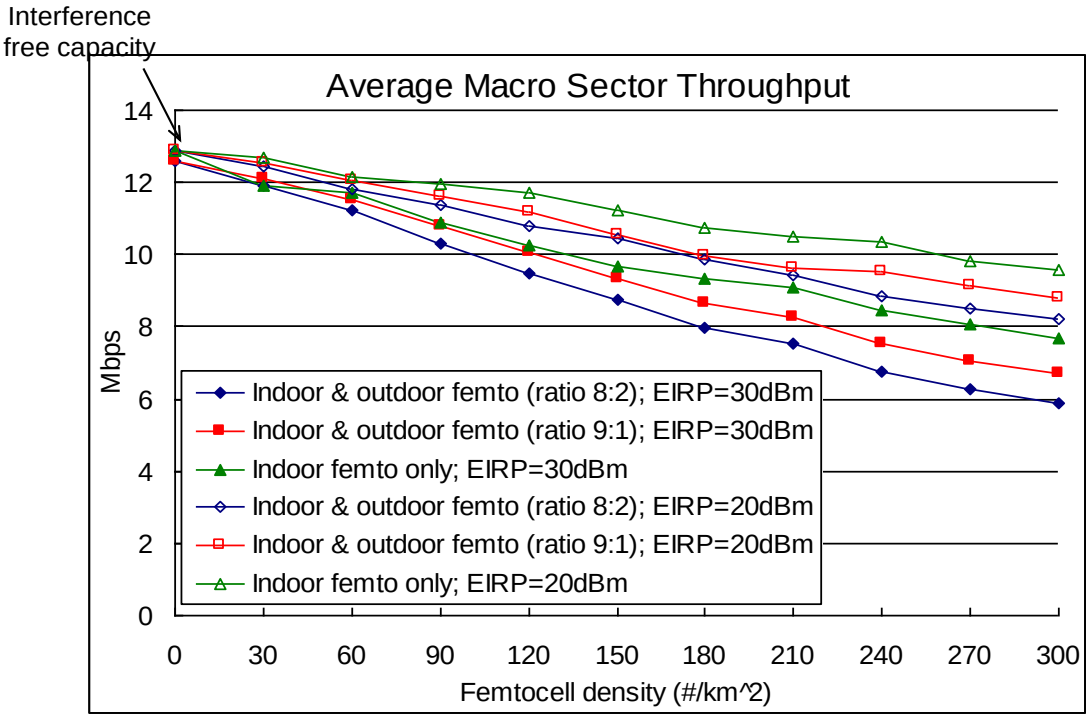
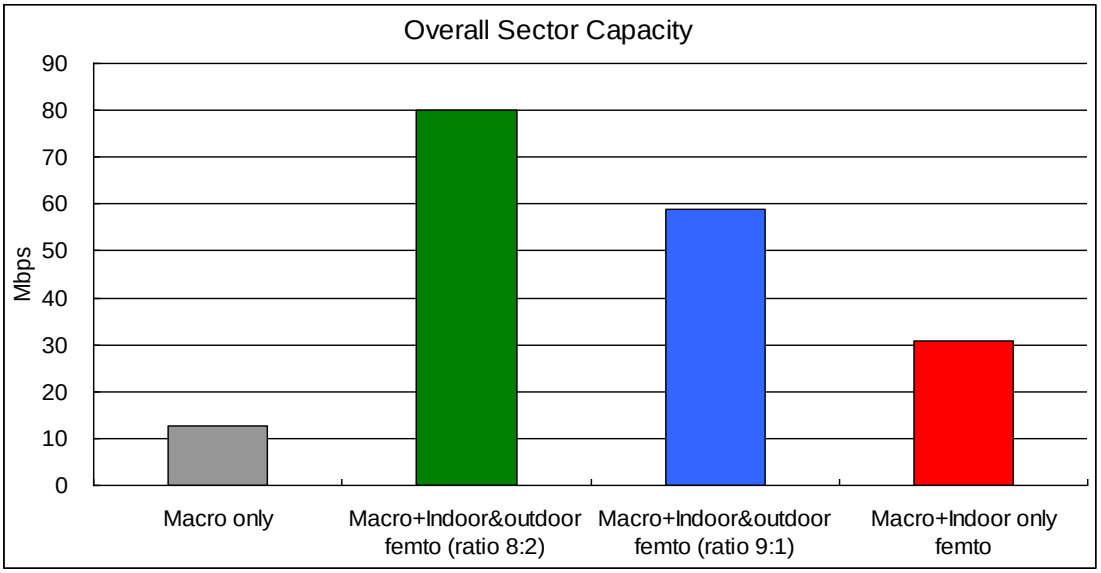


Figure 6: Macro-cellular throughput versus femtocell density



Outdoor femto: full buffer (always have data to send)
Indoor femto: Monthlylimit / (30days*Usagehour*3600*Max downlink) +Monthlytalktime/ (Usagehour*30*60)
Where Monthly limit=2GB, Monthlytalktime=600mins, Usagehour=6. Indoor femto only sends data when needed.

Figure 7: Capacity comparison

C4.2 Conclusions

- Depending on the maximum allowed EIRP and deployment density, femtocells can have a significant impact on macro network coverage and throughput due to co-channel interference,
- This can be mitigated through network roaming between macro and femto operators, deployment coordination, and clever interference management techniques (e.g. power back-off, sub-channelization),
- It is shown that a lower femtocell EIRP limit (e.g. 20dBm) in the shared channel may be necessary to protect the macro network,
- The overall network capacity is significantly improved with femtocells even when there is no roaming or coordination agreement in place.