Use of C-Band spectrum for mobile broadband in cities: London and Shenzhen

November 2015

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Executive Summary

This study provides an independent assessment of the economic benefits that would arise through use of C-Band spectrum (within the 3400-4200 MHz range) for mobile broadband in two major cities – London and Shenzhen.

Mobile broadband traffic is forecast to grow rapidly over the next 10-15 years. It is possible there will be a capacity crunch unless sufficient spectrum is made available to avoid operators having to make costly and unnecessary investments in infrastructure to support this traffic growth. C-Band spectrum could be used to provide additional capacity to address this shortfall. It will reduce costs of provision and increase quality of experience.

3400-4200 MHz is used by several incumbent services including the Fixed Satellite Service (FSS) and the Fixed Service (FS) – fixed links. The analysis of economic benefits undertaken by Plum is based on protecting the continued operation of registered satellite and fixed link services where this is required. This protection will be provided by establishing protection zones for incumbent services, which in turn will allow sharing with mobile services to take place.

The output of the analysis for the study shows that without the additional spectrum made available by earlier release of spectrum in the range 3400-4200 MHz, and the implementation of appropriate national sharing frameworks for use of this spectrum, a capacity crunch will occur in Shenzhen in around 2020 and London in around 2022. If mobile data traffic demand is 30% higher than the forecast the capacity crunch will occur two years earlier in each city.

We have quantified the avoided cost benefit of using C-Band spectrum taking account of the incumbent services and known plans for spectrum release for each city. The benefit from avoided costs is computed as the difference in Net Present Value (NPV) of the total radio access network cost between a base case and an alternative case with greater spectrum availability.

Our analysis shows that the benefit for London would be EUR 275m over the period 2018 to 2028 expressed in 2018 terms and that the equivalent number for Shenzhen would be EUR 126m. In Shenzhen there is less C-Band spectrum potentially available than in London based on the information made available to us for the study. The availability of more C-Band spectrum in Shenzhen could increase the level of benefit seen there. It is expected that similar results would be seen when modelling other large cities.

The results of the study suggest that consideration should be given by governments and regulators to the early release of spectrum in the range 3400-4200 MHz. The likelyhood of a capacity crunch in the early 2020s in both cities indicates that action is required in the short term to deliver regulatory certainty to those making investments in mobile infrastructure and to deliver the quality of experience necessary for social well-being and economic growth.

1 Introduction

1.1 Reason for the study

Plum has undertaken two previous studies[1] on the use of C-Band spectrum (3400-4200 MHz) for IMT. These studies considered the use of the band in a number of European countries and they showed that:

- It is feasible for IMT to achieve realistic sharing scenarios that afford protection of incumbent services using the band (satellite, fixed links and Fixed Wireless Access)[2].
- The early release of the 3400-4200 MHz band[3] will generate a positive economic benefit by reducing the amount of investment required in infrastructure to meet increasing traffic demand.

The results of Plum's previous studies showed that the majority of benefit is obtained in areas or "geotypes"[4] where there is a high traffic density (e.g. hot spots). As these areas almost always occur in cities the next step has been to look more closely at the use of 3400-4200 MHz in two large cities – London and Shenzhen. In this study a complementary analysis to the previous studies has been performed but on a more granular basis appropriate for a city environment.

This study focuses on the economic benefits (avoided costs) of releasing spectrum in the 3400-4200 MHz frequency range for mobile broadband. The two cities were selected as they present a diverse set of conditions that allow the options for sharing with mobile broadband to be fully explored.

1. http://plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_C-Band_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf and http://plumconsulting.co.uk/pdfs/Plum_Oct2014_Economic_benefits_from_C_band_use_for_mobile_broadband_in_UK.pdf
2. Other independent studies performed by Transfinite have shown similar results to those obtained by Plum: Geographic sharing in C-Band (a report for Ofcom May 2015) http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2015/c-band-sharing.pdf
3. Or parts of the band where the whole band is not available (e.g. 3400-3700 MHz or 3400-3800 MHz).
4. We have defined 5 geotypes for this analysis. As the geotypes for this study are specifically aimed at a city environment they differ from those used in the previous Plum studies.

1.2 The need for more spectrum for IMT

In a world powered by demand for information, access to the internet has become increasingly important. Advances in access technology have made accessing the internet over a mobile device (smartphone or tablet) a reality, resulting in a rapid growth in mobile data traffic. Coverage has been the focus of much historic network deployment but as demand for data increases and user and device expectations of performance increase there is a need to focus more on the provision of capacity and delivery of a high quality of service for a more consistent user experience. This triggers a burgeoning need for investments in network infrastructure as well as a need for an increased amount of spectrum.

Capacity crunch

In the absence of more spectrum it will become difficult for mobile networks to handle increasing traffic demand and in areas where demand is very high the practicality of serving traffic by building ever more infrastructure will become unrealistic on the grounds of both cost and issues with locating sites. Constraints on availability of spectrum in these areas could lead to a capacity crunch. The effect of such a crunch will be delivery of a poor quality of service and quality of experience as it becomes more difficult to establish data sessions, download speeds become restricted and latency increases. This in turn will reduce confidence in the ability of mobile broadband to support social well-being and economic growth. It is imperative that spectrum is made available to avoid the prospect of a capacity crunch.

1.3 IMT Technology Assumptions

This study, as part of its estimation of the avoided costs that accrue from use of 3400-4200 MHz, will consider outdoor network deployments. It is increasingly apparent that networks based on macro cell sites will require additional network layers based on small cells, either within the coverage area of a macro cell (intra-cell) or in areas between the edges of cells (inter-cell) in order to allow operators to provide mobile broadband capacity at the right level and in the right locations. This type of network comprising coordinated resources in the macro and small cell network layers is often known as a heterogeneous network. Also, carrier aggregation[5] will become increasingly important in the delivery of capacity using small cells as mobile broadband traffic demand increases (both aggregation on a single cell and aggregation between macro and small cell). Use of carrier aggregation is incorporated in the analysis for both cities studied. The specification of small cells and carrier aggregation is as set out in Plum's previous reports.[6] The use of MIMO also increases the range and throughput possible with C-Band technology.

The IMT technology assumptions used in this report are based on LTE technology. However, 5G mobile networks will likely be deployed during the timeframe covered by this report and some of the assumptions, especially for small cell capability, are likely to change. Because of the uncertainty of timing of these developments, assumptions related to 5G are not considered in this report.

We do not consider indoor small cells in our analysis

Today indoor mobile data traffic is being overwhelmingly carried over Wi-Fi at very low cost. This means that the bulk of the benefit from indoor use of the 3400-4200 MHz band will not come from avoided cost. Rather the bulk of the benefit of deployment of the band indoors is likely to come from an increase in consumer surplus due to the improvement in quality of service. Consideration of this type of benefit is outside of the estimation of benefits performed for this report. The exclusion of the indoor benefit of C-Band deployment in our analysis will lead to our estimate of the benefit from use of spectrum in the range 3400-4200 MHz being a conservative one.

5. See the case studies at Appendix A for examples of carrier aggregation
6. See Sections C3 and D2 of http://plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_CBand_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf

1.4 Current and future use of 3400-3600 MHz and 3600-4200 MHz

Current use

The frequency range 3400-4200 MHz is used by several incumbent services:

- Fixed satellite service earth stations (FSS ES)
- Fixed links (FL)
- Fixed Wireless Access (FWA).

Actual usage varies by location. In the case of London the analysis takes account of the information available for the existing services across the 3400-4200 MHz frequency range. In the case of Shenzhen where such detailed information is not readily available the frequency range 3400-3600 MHz is assumed to be clear of other services and an exclusion of 20 MHz is made for incumbent services in the frequency range 3600-3700 MHz[7]. At this time the spectrum above 3700 MHz is assumed not to be available for mobile broadband services in Shenzhen.

In this study it is assumed that IMT will share with the other licensed services currently using the band. Only protection of incumbent users who hold an individual authorisation is considered. Where incumbent users do not hold individual authorization (e.g. VSATs and receive only terminals – it may be possible for these to be registered and thus obtain protection[8]).

Future use

Increases in traffic demand forecast to occur over the next decade create the need for networks able to handle higher traffic capacity and capable of delivering good quality of service. One of the prime characteristics required of spectrum to meet this demand is the ability to support larger contiguous channels (i.e. 20 MHz channels). The ability to aggregate channels within the frequency range is also an important feature required for the delivery of high capacity services. The frequency range 3400-4200 MHz is a key band below 6 GHz that meets these requirements. It exhibits similar characteristic to other capacity bands such as 2.6 GHz and there is potentially a large amount of spectrum available even when incumbent service requirements have been considered[9]. For example, it will be able to provide reasonable outside coverage and some penetration into buildings.

7. Based on data from a monitoring study performed by the GSMA
8. For example, in the UK where it is possible to register an installation with Recognised Spectrum Access (RSA)
9. It is recognised that the amount of C-Band spectrum available for IMT will be less in regions where there is extensive use of C-Band for satellite services due to adverse weather related propagation conditions. However, even in these regions some use of the spectrum for IMT should be possible, especially when considering the use of small cells where earth station protection zones may be 5km or less.

1.5 Sharing Frameworks

Mobile broadband services operating in the frequency range 3400-4200 MHz will need to share spectrum with the incumbent satellite, fixed link and FWA. In order to make 3400-4200 MHz available to IMT, administrations need to establish national frameworks for spectrum sharing between IMT and the incumbent services (FSS and FS).

National regulatory authorities define criteria for the protection of the incumbent services in the form of maximum permitted interference at the input of the FSS and FS receivers. These limits are then used to calculate the corresponding protection zones or maximum permitted EIRPs of IMT base station sectors (within a restriction zone) so as to avoid harmful interference to the FSS and FS. Administrations have the flexibility to choose the most appropriate approach for defining the technical conditions which the IMT operators would need to comply with. This is described in more detail in Plum's previous report of June 2015[10].

In order to evaluate the economic benefits of the 3400-4200 MHz frequency range, it is necessary to quantify the amount of spectrum that would be available to the mobile broadband service as a result of sharing with the incumbents. While the details of the spectrum sharing mechanisms will be specified by the national administrations, it is nevertheless possible to reasonably quantify lower bounds on the amounts of spectrum that might be available by assuming certain broad sharing approaches.

Sharing for mobile broadband services may be implemented via Licensed Shared Access (LSA) where this mechanism is available, which in turn standardises the interfaces between the various spectrum sharing functions. ETSI is standardising a repository/controller centric architecture for LSA and procedures for establishing and implementing the required technical sharing rules.

1.6 C-Band case studies

A number of studies have been performed on the use of C-Band spectrum for mobile broadband. Some examples of the way in which the spectrum has been used and tests and deployments of technology based on C-Band are shown at Appendix A.

10. See Section 1.4 of http://plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_CBand_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf

2 Study Approach

The key question addressed by the study is to assess the economic benefit of bringing forward the availability of spectrum in the frequency range:

- 3400-3800 MHz and 3800-4200 MHz for London; and
- 3400-3600 MHz and 3600-3700 MHz for Shenzhen.

Figure 2-1 summarises the approach to the analysis. A full description of the methodology used is contained in Plum's previous reports considering use of this frequency range.

Figure 2-1

Overview of the approach to economic benefit estimation

The approach involves the following steps:

- Technical analysis – deriving the size of the areas where potential interference between mobile base stations and satellite earth stations (FSS ES) and mobile base stations and fixed links could occur. Within each of these areas, the study determines the actual amount of spectrum that could be available for IMT based on the spectrum required by satellite and fixed link users.
- Economic analysis – the economic analysis takes the output of the technical analysis and uses it to determine the total spectrum available for IMT in the cities studied[11]. Using this amount of spectrum the total available network capacity is estimated. A number of cases are defined, which are characterised by the frequency sharing scenarios and timing of the C-Band spectrum release. These cases are used to calculate the resulting change in network infrastructure required to handle mobile traffic demand and the cost difference driven by these changes. The total cost associated with the capacity requirement in each case is then computed.
- Economic benefit estimation – the benefit is calculated as the cost that mobile operators could avoid as a result of having access to spectrum in the range 3400-4200 MHz. It is computed as the difference in total radio access network cost between a base case (least spectrum/highest cost) and an alternate case (more spectrum/lower cost, as described above) and expressed in 2018 NPV terms.

2.1 Technical analysis

Prior to undertaking the economic analysis to determine the benefits from avoided costs it is necessary to determine the amount of spectrum that is available for mobile services in any geographic area along with the number of people for which that spectrum is available. For this study the city areas are expressed using a grid of 1 x 1 km squares.

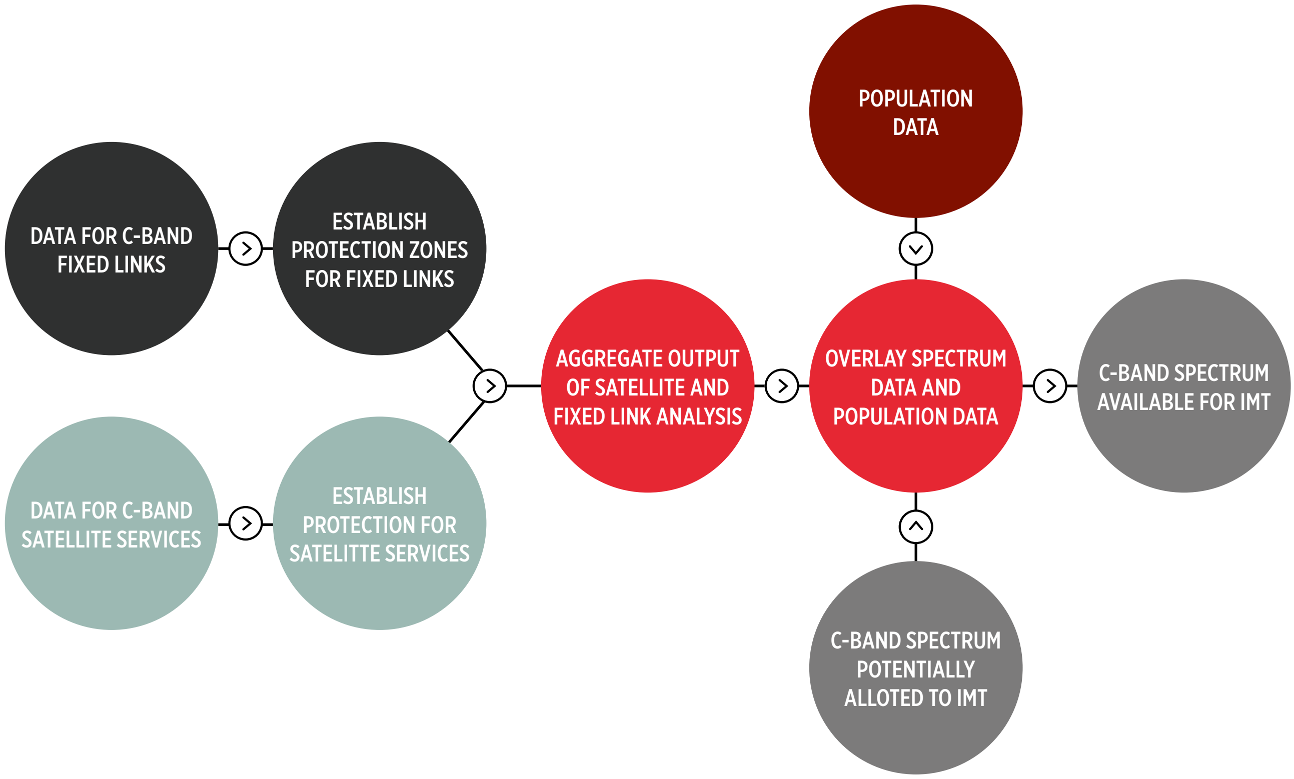
For the purposes of this report it is assumed that the presence of incumbent services using some portion of the frequency band prevents mobile use of that portion of the frequency band in certain areas. This effectively identifies frequency-specific protection zones for incumbent services.

To do this it is necessary to combine a model of frequency and geographic areas around fixed links and FSS ES receiving signals in 3400-4200 MHz with a model of population by area obtained for each city. The approach used is shown in Figure 2-2. Details of the methodology used are fully described in Plum's report of June 2015[12].

11. That is the C-Band spectrum available plus all other IMT spectrum available
12. See Section 2 of http://plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_CBand_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf

Figure 2-2

Establishing the C-Band spectrum available for mobile broadband services



2.2 Technical analysis results

The technical analysis is a two-step process:

i. The first step determines the amount of spectrum that is precluded from mobile use and over what area[13]. The output of this step is the aggregate output of satellite and fixed link analysis shown above.

ii. The second step maps the precluded spectrum/areas onto population data.

The output from this modelling, namely the areas where differing amounts of spectrum are not available to a certain number of people for mobile use, is then subtracted from the whole frequency band to give the spectrum that is available by area and number of people. The population and spectrum availability data is then input to the economic analysis.

13. Note that for this report only the ITU-R criterion has been used for determining the areas in which mobile services would not operate.

2.3 Economic analysis

The economic benefit is estimated as the potential change in cost that operators could experience from having access to larger amounts of spectrum compared to a base case. Table 2-1 shows the assumptions for release of spectrum in each of the study cities.

Table 2-1

Timing of assumed release dates for all study countries

	Expected release dates			Assumed early release dates		
	3400-3600 MHz	3600-3800 MHz	3800-4200 MHz	3400-3600 MHz	3600-3800 MHz[14]	3800-4200 MHz[15]
London	2016	2022	2028	2016	2020	2022
Shenzhen	2019	2023	N/A	2016	2020	N/A

Having access to more spectrum at any given point in time will in general allow operators to roll out fewer base station sites to support the same volume of mobile data. This leads to a lower network cost. Therefore, the total benefits in the modelled scenarios come from the operators having the same amount of spectrum as in the base case but at an earlier point in time[16].

The type of benefit described above is known as avoided cost. As noted in Section 1.3 we have not included indoor small cells in our analysis.

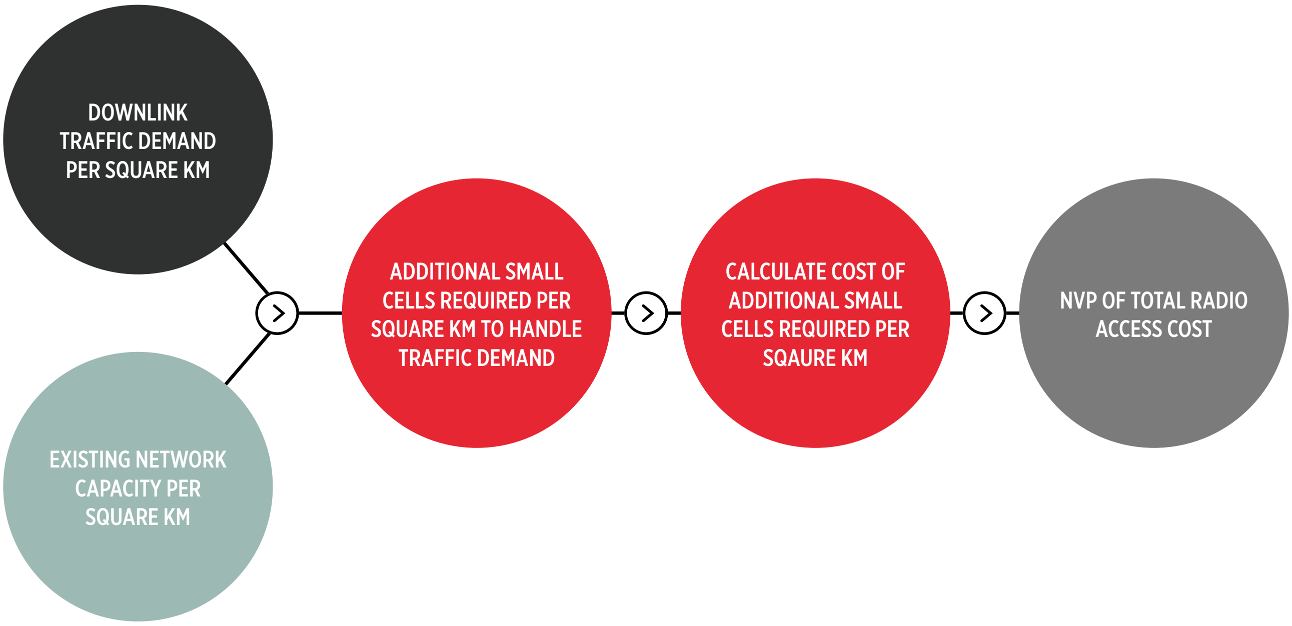
14. 3600-3700 MHz in the case of Shenzhen
15. 3700-4200 MHz in the case of Shenzhen
16. The use of the link performance aware and advanced frequency sharing cases used in previous Plum reports are not considered in this analysis

2.4 Deriving the avoided costs

Figure 2-3 provides a high level overview of the steps used to derive the costs that form the input to the calculation of the avoided costs. Details of the methodology used are fully described in Plum's report of June 2015[17]

Figure 2-3

High level overview of the steps to calculate radio access network cost for all areas and for all bands including C-Band (in the 2018-2027 time frame)



The benefit from avoided costs is computed as the difference in NPV of total radio access network cost between a base case and an alternative case with greater spectrum availability – i.e. Benefit equals (Base Case's cost NPV)[18] minus (Alternative Case cost NPV) . Geotypes are used to ensure that the variation in subscribers and site density in different areas across the cities is captured. There are 5 geotypes, which are defined by day-time population[19] density thresholds as shown in Table 2-2.

17. See Section 3 of http://plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_CBand_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf
18. Note that we assume no change to market structure when performing the analysis. That is no new entry or the exit of an existing operator from the market. The base cost relates to the cost of the existing operators in the market.
19. For London, this is estimated based on day-time population data by borough from ONS (http://data.london.gov.uk/dataset/daytime-population-borough). In the absence of data for Shenzhen, the ratio of day-time population to residential population for London is used to adjust residential population for the city from Gridded Population of the World.

Table 2-2

Geotype definition

Geotype	Population density per sq km (p)
Hot spot	200,000 < p
Dense urban	40,000 < p < 200,000
Urban	15,000 < p < 40,000
Light urban	5,000 < p < 15,000
Suburban	p < 5,000

The concept of heterogeneous networks is incorporated into the analysis by making the assumption that all new cells will be small cells subsequent to 2015. Small cells will only be rolled out when all available bands (including C-band if co-existence and protection requirements allow) have been deployed on existing macro-cell sites and there is still capacity shortfall. Where small cells are rolled out, it is assumed that only bands at or above 2600MHz will be used on them.

2.5 Traffic demand forecast

The key demand-side input is the amount of traffic that operators will need to support. The traffic demand forecasts are constructed from public sources, including Cisco VNI and regulators' reports on historical data traffic, and exchanges with mobile operators in similar environments.

Where possible the forecast is derived by extrapolating the Cisco VNI short-term projection to 2028 using a Gompertz curve. This extrapolation then is adjusted using historic mobile data volume information from regulators. The resulting forecast is then scaled for the city being studied based on population, taking account of the temporary movements of people in the cities from workers and others travelling in on a daily basis.

Long-term projections of mobile data traffic demand are inherently uncertain. Usage behaviour beyond the next few years will depend on both the availability of devices and applications, the quality of the experience that can be delivered and the associated supply side cost. The latter will also determine the extent of mobile device data offload to Wi-Fi and residential indoor small-cells.

2.6 In-band backhaul use

The analysis also considers the use of C-Band for in-band backhaul. The use of C-band or 2600MHz TDD spectrum for backhaul is assumed to apply only for outdoor small cells. We assume that microwave and fixed connections will continue to be used for backhaul on macro cell sites (and some small cell sites). The use of in-band backhaul for small cells means that not all of the spectrum available can be used for radio access. To ensure that backhaul capacity is guaranteed for small cells, half of available spectrum for IMT in the C-Band is assumed to be reserved for backhaul. Implicit in this assumption is that operators do not incur annual spectrum fees on backhaul for small cells.

2.7 Spectrum supply in the Base Case

Spectrum is an important supply-side input. It determines the level of existing capacity for comparison with demand. The amount of available downlink spectrum across all frequency bands in each of the cities studied can be found in Sections 3 and 4.

3 London

3.1 Technical analysis

There are two incumbent service types present in the London area: FSS ES and fixed links. The fixed links traverse the Greater London area from east to west and require protection. There are also FSS ES around London, which require protection. Figure 31 shows the impact of the protection of incumbent services on the availability of C-Band in the London area. Note that the figure below shows the effect on spectrum in the range 3600-4200 MHz (i.e. 600 MHz of spectrum)[20].

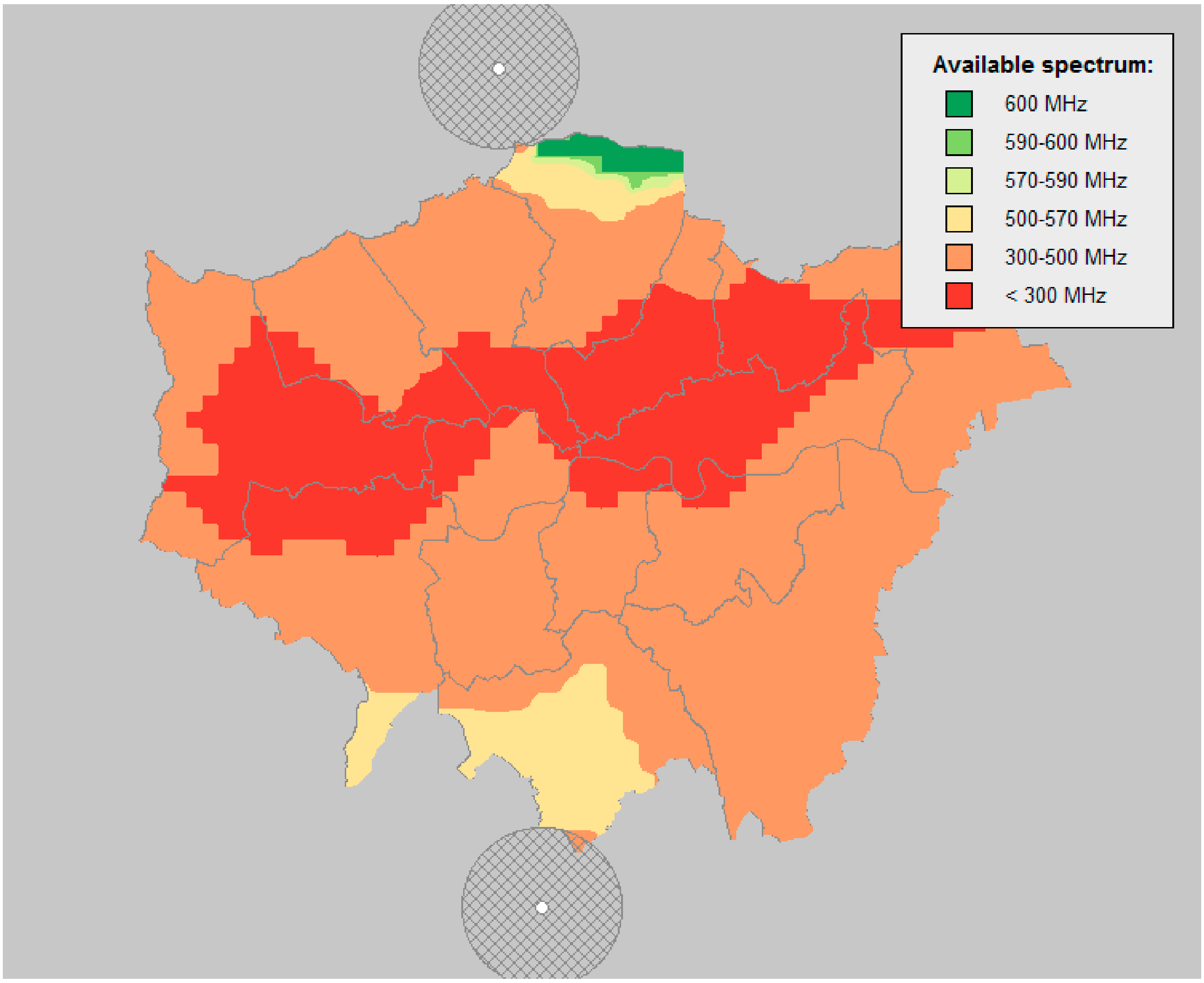
The proximity of the FSS ES to London would significantly reduce the amount of C-Band spectrum if macro-cells are deployed in London using the band. For this reason C-Band is assumed not to be deployed on macro cells in London and it is only deployed on small cells. Under these conditions it is possible to achieve the 5km protection zone required for the FSS ES with only a minor reduction of C-Band spectrum on the edges of the Greater London area. The two FSS ES installations just impinging the boundary of Greater London are clearly shown on the map.

The effect of the C-Band fixed links in the Greater London area on the availability of 3600-4200 MHz spectrum can clearly be seen in the reduced availability of spectrum (coloured red) running east-west across the map. in Figure 3-1.

20. For the model it is assumed that spectrum in the frequency range 3400-3600 MHz is part of the counterfactual as 40 MHz of this spectrum is already held by UK Broadband and 150 MHz will be brought to market by Ofcom in early 2016. See http://stakeholders.ofcom.org.uk/binaries/consultations/notice-2.3-3.4-ghz-spectrum/summary/notice.pdf

Figure 3-1

C-Band spectrum availability in London



3.2 Spectrum Availabilty

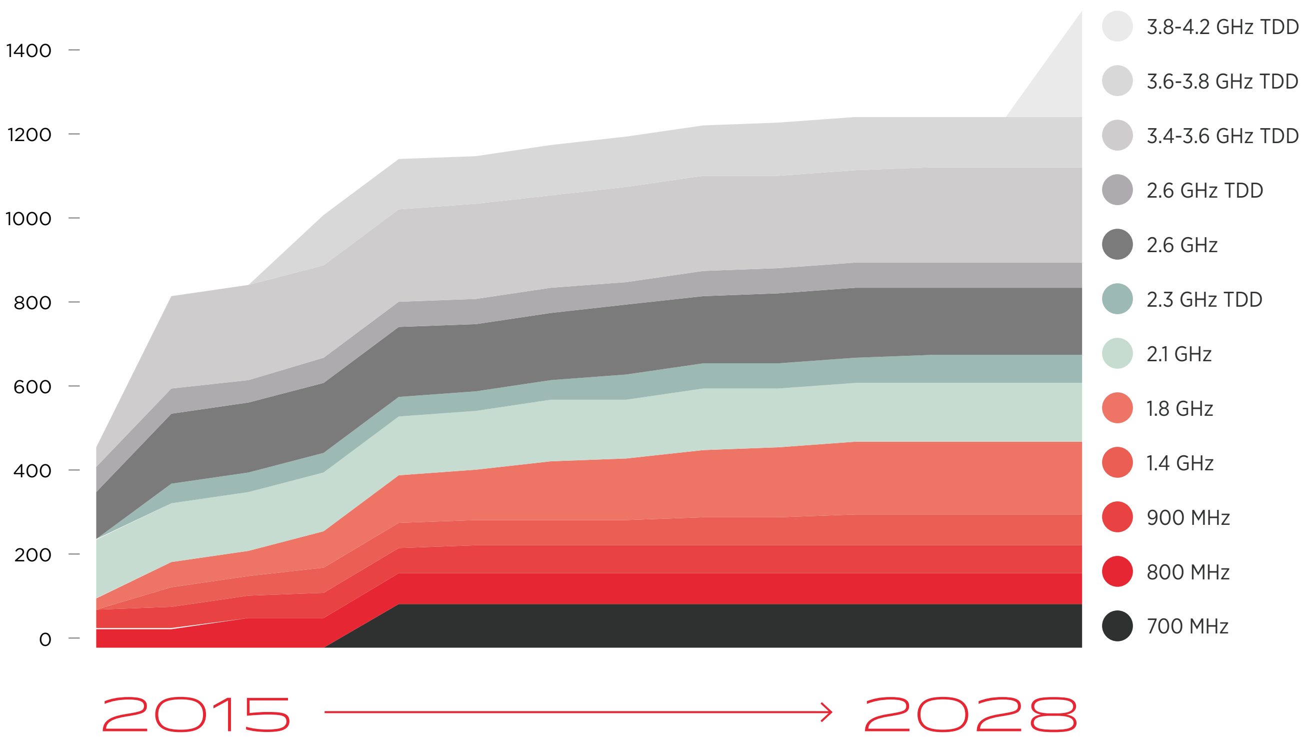
Figure 3-2 shows the maximum spectrum available for mobile broadband over time in the base case. The spectrum shown is for both macro cells and small cells. However, not all bands are used on both cell types due to coexistence restrictions.

Figure 3-2

Source: Plum Consulting

Maximum available spectrum in London

Base case spectrum in MHz



It is assumed that some spectrum in the 900MHz and 1800MHz bands will continue to be reserved for 2G voice service until at least 2020. Based on Plum's technical analysis on coexistence, the maximum amounts in the 3600MHz-3800MHz and 3800MHz-4200MHz ranges that can be used for mobile service are 105MHz and 215MHz respectively.[21]

21. These are the amounts of spectrum averaged across the geographical area studied for the "hot spot" geotype

3.3 Traffic demand forecast

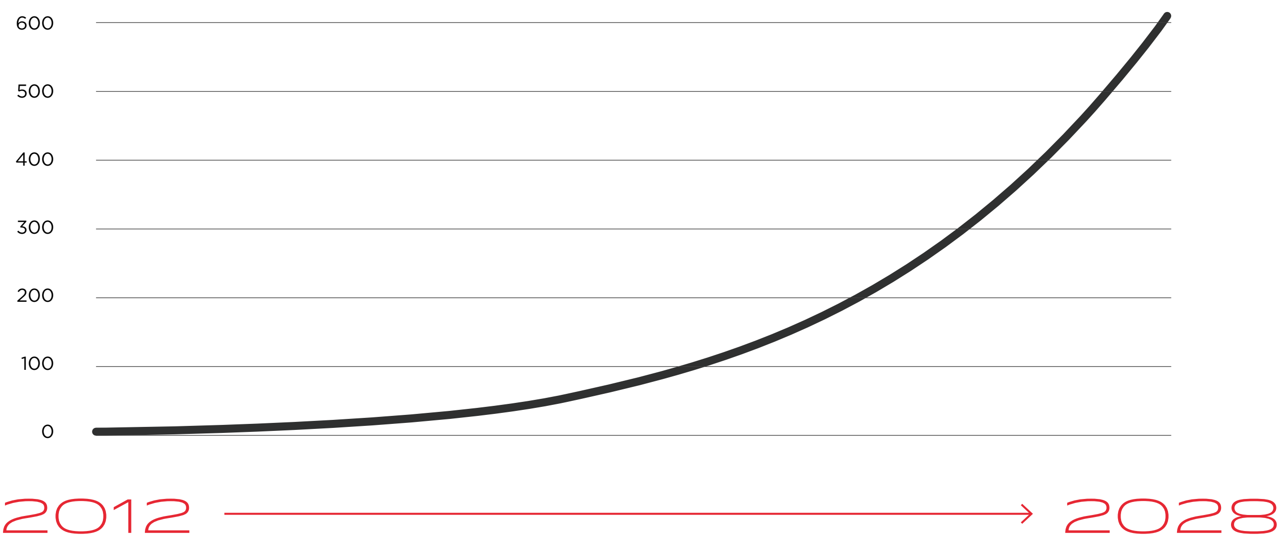
The traffic forecast for London is shown in Figure 33.

Figure 3-3

Source: Ofcom, Cisco VNI, Plum Consulting

Mobile data traffic projection in London

PB per month



London's projection is derived by extrapolating the UK's Cisco VNI 2014 short-term (2012-2018) projection to 2028 using a Gompertz curve. This is then is scaled using historic mobile data volume information from regulators. This forecast shows 2014 number which is consistent with what Ofcom reported for June 2014 in their Infrastructure Report released in November 2014. The resulting forecast is then scaled for the city being studied based on population compared to the whole of the UK, taking account of the population uplift in the cities from workers and others travelling into London on a daily basis.

3.4 Benefit

Based on the traffic forecast, Plum's economic model shows that operators will start to build new infrastructure when they experience a capacity constraint on their network in 2022. This means that additional spectrum released before then will enable them to save on network costs, which are likely to be passed on to consumers in a competitive market. In total, the benefit in avoided cost terms (2018 NPV) is EUR 275 million.

4 Shenzhen

4.1 Technical analysis

Detailed incumbent service data was not available for Shenzhen. The assumptions made for modelling purposes are that the frequency range 3400-3600 MHz will be fully available from the date shown in Table 21 and that the frequency range 3600-3700 will be available from the date shown in Table 21 with the exception of a 20 MHz exclusion to protect incumbent services across the whole area. C-Band spectrum above 3700 MHz is assumed not to be available in Shenzhen.

4.2 Spectrum availability

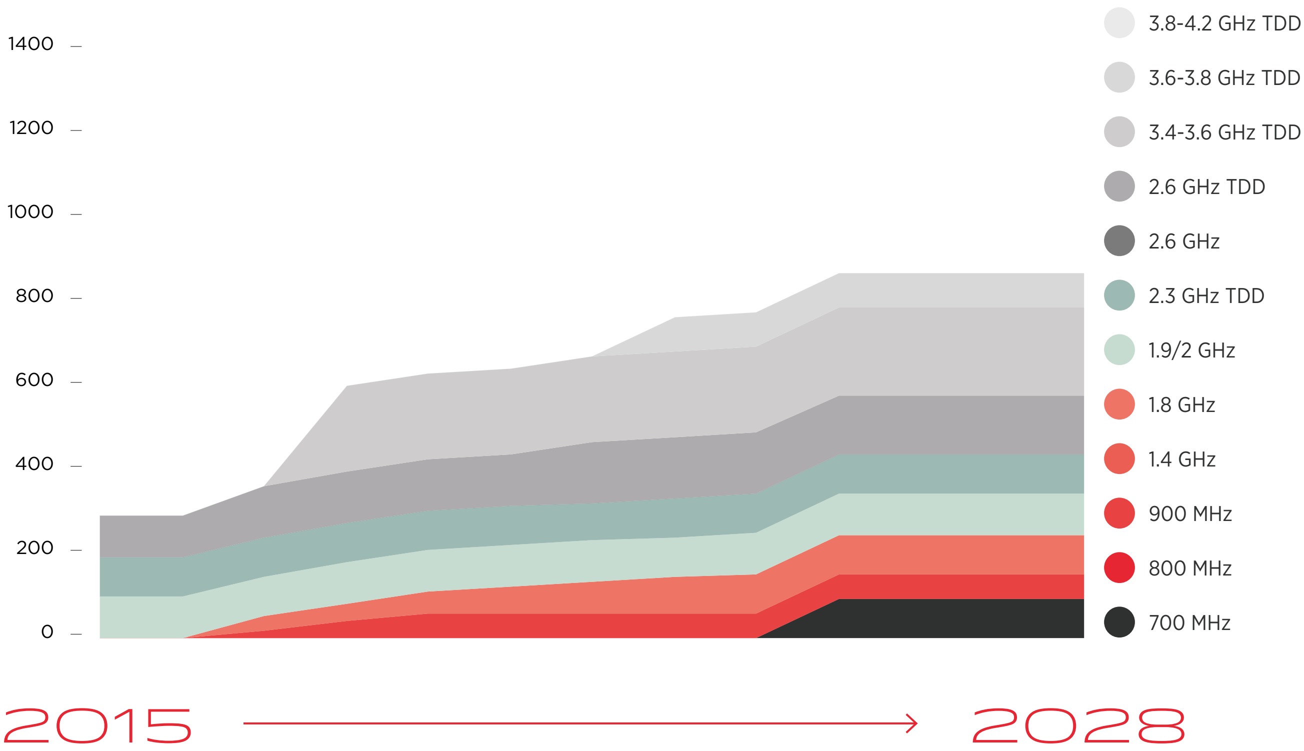
Figure 4-1 shows the maximum spectrum available for mobile broadband over time in the base case. The spectrum shown is for both macro cells and small cells.

Figure 4-1

Source: Plum Consulting

Maximum available spectrum in Shenzhen

Base case spectrum in MHz



It is assumed that some spectrum in the 900MHz and 1800MHz bands will continue to be used exclusively for 2G voice service until at least 2018. Unlike in London, where incumbent satellite service means that the C-Band above 3600MHz is only usable on small cells, it is assumed that available frequencies above 3400MHz can be deployed on both macro cells and small cells.

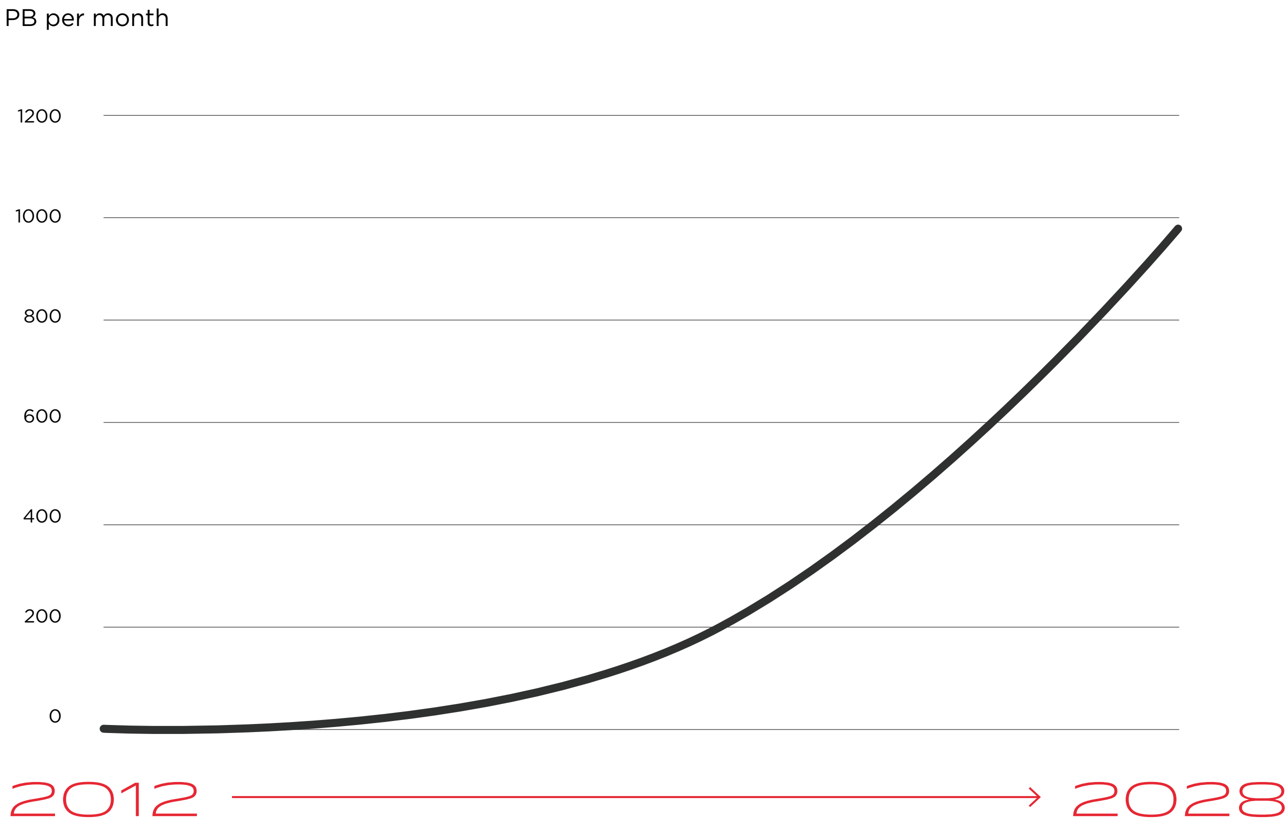
4.3 Traffic demand forecast

The traffic forecast for Shenzhen is shown in Figure 4-2.

Figure 4-2

Source: Ofcom, Cisco VNI, Plum Consulting

Mobile data traffic projection in Shenzhen



Due to a lack of usage data for big cities in China, the historical mobile traffic for the city is derived based on information from public sources for developed East Asian countries and previous exchanges Plum had with operators in these localities. A similar growth path as for London is then assumed from historical traffic estimates from 2014 to build forecasts for Shenzhen to 2028. In this projection, traffic volume is assumed to grow at an annual rate of 39% on average between 2015 and 2030.

4.4 Benefit

Based on the traffic forecast, operators are expected to build new infrastructure when they experience a capacity constraint on their network in 2020. The total benefit in avoided cost terms (2018 NPV) is EUR 126 million.

5 Conclusions

5.1 Use of C-Band spectrum

The early availability of 3400-3800 MHz and 3800-4200 MHz spectrum in the case of London and 3400-3600 and 3600-3700 MHz spectrum in the case of Shenzhen is expected to yield significant net benefit through avoided infrastructure costs. This spectrum potentially offers the large contiguous blocks that will be required for mobile broadband use as mobile data traffic grows. The actual magnitude of the benefit is dependent on a number of factors including demographics, the density of incumbent services and projected traffic growth.

The analysis suggests that a capacity crunch occurs in London around 2022 and Shenzhen around 2020 in the absence of the earlier availability of this spectrum. This result is based on the relatively conservative mobile data traffic demand forecasts used for modelling the avoided costs. If mobile traffic demand were to grow more aggressively the spectrum crunch would occur earlier. For example if demand is 30% higher than forecast the capacity crunch occurs in 2020 in London and 2018 in Shenzhen (i.e. 2 years earlier). The presence of a capacity crunch will lead to a degraded quality of service and experience for users. While it is possible to continue to split cells and provide more infrastructure to mitigate the effects of the crunch, use of this approach to capacity provision will lead to rapidly increasingly infrastructure costs and reduced network efficiency. The presence of more spectrum will mitigate the effects of the crunch and reduce infrastructure costs.

The use of the band for mobile broadband is made possible by the implementation of sharing with incumbent services. Previous studies by Plum and others have established the feasibility of sharing with incumbent services. The benefits set out here have been estimated on the basis of protecting the continued operation of registered satellite and fixed link services where this is required.

The results of the study suggest that consideration should be given by governments/regulators to the early release of spectrum at 3400-4200 MHz. The likelihood of a capacity and therefore a spectrum crunch in the early 2020s in both of the cities studied indicates that action is required in the short term to deliver sufficient predictability and regulatory certainty for potential users of the band in high traffic demand areas. It is expected that similar results would be obtained when modelling other large cities.

5.2 Benefits

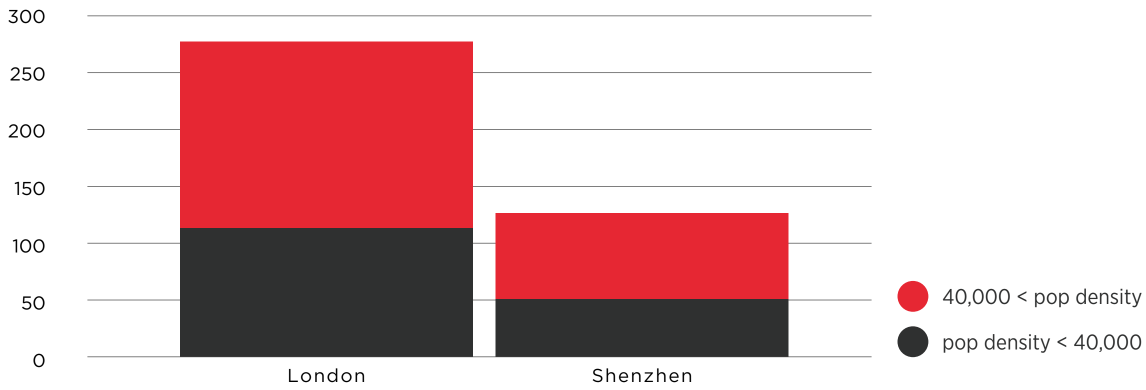
The total benefit from the deployment of C-Band spectrum in the two cities is EUR 401m expressed in 2018 terms over the period 2018 to 2028. It can be seen from the results that the benefit for Shenzhen is smaller than that for London (EUR 126m vs EUR 275m). There are several reasons for this including that Shenzhen already has a higher mobile base station density than London and that there is less C-Band spectrum potentially available for mobile broadband use in Shenzhen based on the assumption made for the model, which were derived from our current understanding of the future use of the band in Shenzhen. The availability of more C-Band spectrum in Shenzhen would potentially increase the benefit. The benefits for both cities split by dense and less densely populated districts are shown in Figure 5-1.

Figure 5-1

Source: Plum Consulting

Benefits by areas

EUR million in 2018 NPV terms



5.3 Conservative assumptions

It should be noted that some of the assumptions used to model the benefit are conservative and as a result the avoided cost is likely to be underestimated. Factors likely to produce a conservative result are:

- No benefits (consumer surplus) are included from use of C-Band spectrum for indoor small cells.
- The benefits associated with the contribution that the 3400-4200MHz frequency range would give to the innovation of mobile broadband networks and in particular to the establishment of 5G have not been quantified within the avoided cost model.
- Benefits from enhanced quality of service and experience to provide consistent performance across the whole coverage area were not taken into account.

Case Studies

3.5 GHz in China

China intends to release 3.4-3.6 GHz in the near future. From an ecosystem point of view to form a 400 MHz frequency pool in the range 3.3-37 GHz is also important in China.

3.5 GHz equipment is becoming a reality. A variety of indoor and outdoor base stations/small cells are available together with a range of CPE. While initially the focus has been on fixed CPE, commercially available3.5 GHz mobile devices are expected to be more widely available in the near future.

A number of demonstrations / trials to show the operation of 3.5 GHz TD-LTE have been carried out in China with Huawei and China Mobile. These have included drive tests with dual carrier aggregation and tests with 5 carrier aggregation. The latter which was implemented with a configuration of 5 carriers aggregated, 256QAM and 4x4 MIMO demonstrated a peak data rate of 1.2 Gbps.

Outdoor field trials have so far shown that coverage of 3.5 GHz is only slightly worse than 2.6 GHz. Larger scale trials are planned for testing coverage, throughput, control and data plane latency, network quality and enhanced features such as carrier aggregation.

These trials will also look at solutions for coexistence to protect existing satellite earth stations.

Figure A-1

3.5 GHz Outdoor Field Trials

Coverage comparison between 3.5GHz and 2.6GHz

3.4 GHz LTE-A demonstration in Tokyo

Tokyo is a city with a highly concentrated population who make extensive use of mobile communications. Providing capacity to meet traffic demand is a challenge operators will increasingly face as demand increases. 3.4 GHz spectrum will provide a solution for the provision of the higher capacity networks must provide.

A trial was performed in the Ginza area of Tokyo in 80 MHz of 3.4 GHz spectrum. It involved 9 base station sites. The trial made use of MIMO, 4 carrier aggregation technology and heterogeneous network techniques. Specific geographic zones were established to demonstrate different techniques. The layout of the sites was established to work with the topology of the district (i.e. the buildings and other features of the terrain).

The demonstration showed how 3.4 GHz spectrum could be used to deliver capacity for the future.

Figure A-2

3.4 GHz LTE-A Trial Network in Ginza

Coverage comparison between 3.5GHz and 2.6GHz

UK Broadband

The UK is a vibrant broadband market. Smartphone and other mobile devices are driving mobile broadband access and while the demand for fixed access is being served by cable and ADSL/VDSL solutions, there is an opportunity for a fixed wireless access solution. UK Broadband is seizing this opportunity.

UK Broadband holds 3.4 GHz spectrum and it is focusing on building 4G networks in major cities. It has launched service in Greater London in June 2014 under the brand name "Relish". It plans further rollout in other major cities and will add rural coverage in future.

Relish offers a fixed wireless access service for residential and business customers and a mobile service to a pocket hub which acts as a personal Wi-Fi router. Users are offered a range of data plans depending on their data requirements.

The service is based on use of 3.4 GHz technology. For residential and business users the service will deliver up to 50 Mbps depending on the location of the receiving node. The service operates in spectrum which Ofcom has already released for the provision of fixed/mobile communications services.

Figure A-3

Advanced 4G Network Ensures Customer Experience

Glossary

ES	Earth Station
FS	Fixed Service
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
IMT	International Mobile Telecommunications
LSA	Licensed Shared Access
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
NPV	Net Present Value

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