Spectrum reassignment in Hong Kong - the case of the 1.9-2.2GHz band

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Table of Contents

1 Summary

In March 2012 OFCA published its first consultation[1] on the arrangements to apply to spectrum in the 1.9 to 2.2 GHz band (2.1 GHz spectrum[2]) when licences for existing assignments expire in October 2016. At present there are four mobile operators assigned spectrum in the band –CSL, HKT, Hutchison and SmarTone (3G licensees) and each uses the spectrum to operate a 3G network. A fifth operator China Mobile also offers 3G services as an MVNO on one or more of the 3G networks. All five operators also offer 2G and 4G mobile services. In December 2012 OFCA published its second consultation[3] which makes further proposals on the arrangements and more detailed proposals for the setting of the Spectrum Utilisation Fee (SUF) to apply to 2.1 GHz spectrum.

Plum was commissioned to review the proposals in OFCA's first consultation and it has now been commissioned by the 3G licensees to provide an independent appraisal of the technical and economic consequences of the arrangements proposed in the second consultation and to critically examine the basis for establishing the SUF.

1.1 The case for Option 1

Contrary to the clear benefits of Option 1, OFCA states in its second consultation that its proposed choice for assignment on expiry of 2.1 GHz spectrum is Option 3:

- Option 2 is discounted on the basis of public interest considerations (primarily on service continuity grounds).
- Option 1 is discounted on the basis that there are competing demands for the 2.1 GHz spectrum and that there are not overriding public policy reasons for supporting Option 1. OFCA argues that while service continuity would be best served by Option 1, Option 3 will lead to a better outcome in terms of efficiency, investment, innovation and competition.

Plum's conclusion is that Option 1 best meets the needs of the Hong Kong market with the least disruption to service for consumers at a time when mobile data traffic is growing rapidly. Option 1 is consistent with the approach adopted previously in Hong Kong for renewal of licences in utilised bands. It is the least cost approach for 2.1 GHz spectrum on expiry of the existing licences and it is the option most likely to deliver relatively low price levels to consumers. Options 2 and 3 created uncertainty from December 2012 when the second consultation was published, which inhibits innovation, investment and efficiency, which in turn could have a dampening effect on competition. Options 2 and 3 would raise industry costs, which would be passed onto consumers.

With the rapid growth in mobile data traffic forecast for the next 5 years making any changes that disrupt Hong Kong's ability to serve mobile data demand will be damaging to consumers and Hong Kong's reputation as an advanced communications hub. In the event that in October 2016 an incumbent operator lost some or all of its 2.1 GHz spectrum assignment there will be a significant reduction in the quality of service delivered to customers using 3G services and significant (and unnecessary) disruption costs. A reduction in quality could be manifested as temporary loss of service,

[1] Arrangements for the Frequency Spectrum in the 1.9 – 2.2 GHz Band upon Expiry of the Existing Frequency Assignments for 3G Mobile Services – Consultation Paper – 30 March 2012

[2] Note that in this report the term 2.1 GHz band/spectrum means the radio spectrum 1,920 MHz to 1,980 MHz and 2,110 MHz to 2,170 MHz (i.e. 2 X 60 MHz of spectrum).

[3] [3] http://www.coms-auth.hk/filemanager/en/share/cp20121228.pdf

inability to make calls/set up mobile data sessions, response delay, dropped calls, broken data sessions and problems with roaming

Table 1-1 shows Plum's view of the relative merits of Options 1 to 3 against the criteria set out by OFCA. In the table we have used a scale of 1 to 5 where 5 is the best outcome and 1 the worst outcome.

Table 1-1: Relative merits of options

	Option 1	Option 2	Option 3
Service continuity	**5**	**2**	**3**
Encouragement of investment and of innovative services	**5**	**2**	**2**
Efficient spectrum utilisation*	**--**	**--**	**--**
Promotion of effective competition	**3**	**1**	**1**

*No existing measures are available from OFCA on which to judge this criterion. However, the high level of competition which now exists in the Hong Kong market would suggest that spectrum is currently being used efficiently.

As can be seen from the table, Option 1 best meets all of OFCA's criteria and hence Plum recommends that it should be implemented in Hong Kong. Below we look at each of the criteria in turn.

Service continuity

OFCA recognises that only Option 1 preserves customer service continuity with minimum risk. Option 2 creates risks of the loss of an incumbent operator's entire 2.1 GHz spectrum holding while Option 3 reduces that risk somewhat. Loss of 2.1 GHz spectrum and the resulting loss of capacity create network congestion and will require:

- Migration of some or all customers from the deprived 2.1 GHz spectrum to other services/spectrum blocks due to service congestion and degradation.
- Significant network re-engineering to maintain quality of service where possible, which results in inefficient investment (i.e. investment that provides no net improvement in consumer outcomes compared with Option 1).
- A shift of resources to managing the challenges arising from the implementation of Options 2 or 3 that could be used to better serve customers in other ways. This is an inefficient use of investment funds and represents wasted and inefficient use of resources.

All of the above have an adverse impact on consumers and give rise to significant disruption costs.

Encouragement of investment and promotion of innovative services

Option 1 is most likely to foster an environment where investment and innovation occur effectively. Options 2 and 3 will create uncertainty for the incumbent 2.1 GHz operators who will be faced with having to factor into all their strategic activity the prospect that some of their 2.1 GHz spectrum will be lost. This could in turn inhibit operators from investing, innovating and competing as aggressively as they could have done under Option 1. Table 1-2 expands on this.

Table 1-2: Investment and innovation

Option1	Option 2	Option 3
The minimal disruption caused to 3G services by this option allows operators to focus on forward looking investment strategies across all services, their current spectrum portfolio and to properly assess the risk and opportunity of new spectrum coming to market. It also removes much of the uncertainty in the period from 2013 allowing operators to focus on the development of innovative services and to promote these.	The prospect of an operator losing its entire 3G spectrum at auction will remove any incentive for future investment in services using 2.1 GHz technology. This necessitates an operator completely rethinking its technology, product and services roadmap. The resulting outcomes will be sub-optimal relative to those that would occur with the 3G spectrum. If investment in 4G services is forced by a regulatory decision then the investment is sub-optimal. See Option 3 for the case where auction results in a partial loss of spectrum at 2.1 GHz	While the outcome of Option 3 might not be as severe as that for Option 2 it could still require an operator to change its technology, product and services roadmap with similar negative implications for the development of innovative services and the promotion of these.

Efficient spectrum utilisation

The development of mobile services in Hong Kong, the intense competition which OFCA acknowledges exists and the rapid growth of mobile data traffic all suggest that the usage of 3G spectrum in Hong Kong is efficient. OFCA's consultation papers do not present any concrete evidence to the contrary. Indeed, spectrum fragmentation through the creation of additional spectrum blocks out of the existing 2.1 GHz blocks could result in less efficient spectrum utilisation. If OFCA has significant doubts in this regard it should examine the current utilisation of 2.1 GHz spectrum and how this will change in the period to 2016 with mobile data traffic growth to reassure itself that the spectrum is being used efficiently. If this analysis has already performed the results should be made available.

Promotion of effective competition

The Hong Kong market is already fiercely competitive. Both consultations recognise this.

It is unclear to us that further entry into the 2.1 GHz band for provision of 3G services will create a positive economic benefit given the already intense competition between 3G operators – it is more likely that benefits will flow between operators in such a situation and any benefits be outweighed by

disruption costs. Moreover, as noted above, deterring investment and innovation by existing operators may in turn dampen competition until the current licenses expire in October 2016.

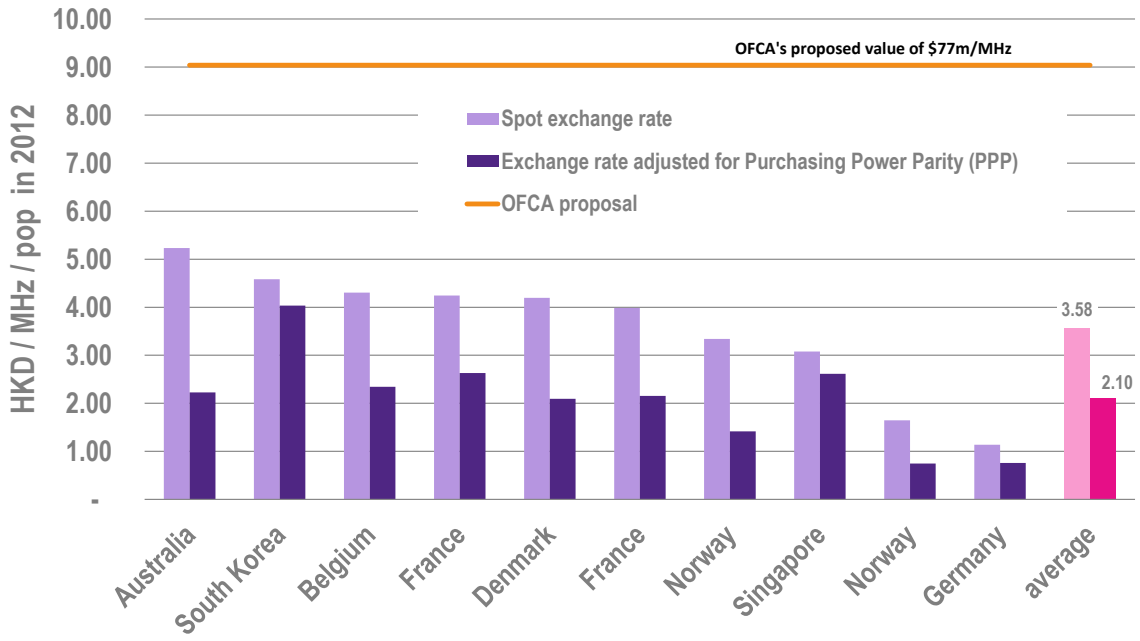
Furthermore there is a spectrum release plan allowing further opportunities for market entry and current holdings of spectrum already capable of supporting LTE services. The deployment of these services will act as a competitive spur to the market and provide new opportunities for existing and potentially new players in the market. We would suggest that new spectrum release, the liberalisation of 2G spectrum and the development of a spectrum trading regime would be more likely to yield competitive benefits than the use of Options 2 or 3.

Given the uncertain nature of benefits arising from the re-auction of 2.1 GHz spectrum, it is crucial that any decision to adopt Option 3 is backed up by a rigorous economic impact assessment. A robust assessment should consider all the potential outcomes from an auction of 2.1 GHz spectrum and both costs and benefits should be quantified for each outcome. Any partial analysis that does not closely match real and quantifiable benefits with the corresponding costs will introduce bias into the decision making process.

1.2 SUF

OFCA needs to set an SUF for the right of first refusal (RFR) spectrum for Option 3. The values proposed by OFCA in its second consultation are too high (see Figure 1-1).

Figure 1-1: Value/MHz/pop of 2.1 GHz auctions in high income countries



Note: Values have been normalised to 15 year licence duration.
Source: Plum Consulting, Regulators' websites

This is because of deficiencies in the way OFCA has derived these values. In particular:

- OFCA has not taken account of the need to discount future values to give a lump sum value for the SUF in 2016.
- OFCA has not recognised that the final year payment for the 2.1 GHz licences is likely to overstate the annual value of spectrum over the current licence period. There is no evidence values are increasing over time (in nominal or real terms) and so this value cannot be said to provide a good indicator of future value.
- OFCA has not taken account of the fact that the 2.1 GHz operators were awarded 5MHz of TDD spectrum, as well as the FDD blocks, in 2001.
- OFCA has not taken due account of the characteristics of different frequency bands when using historic Hong Kong benchmarks and so has overestimated the value of the 2.1GHz band.
- OFCA has not taken into account relevant international benchmark values.

The net result is that OFCA's estimates of the value of the 2.1 GHz band are more than double the value justified by either the current 2.1 GHz payment schedule and up to four times the relevant international benchmarks.

Regulators elsewhere have made use of international benchmarks to inform their view of the market value of spectrum and to set reserve prices in auctions (e.g. in Australia, Greece, Ireland, New Zealand and the UK). So which historic auction results give appropriate benchmarks for setting an SUF for the 2.1 GHz band?

Ideally we would use recent Hong Kong benchmarks; however, these apply to different bands with different characteristics from the 2.1 GHz and give a very wide range from $5m/MHz (2.3 GHz in 2012) to $108m/MHz (900 MHz in 2011). The 2.1 GHz market value should clearly fall within this range but where? The payments for the existing 3G licences (adjusted for inflation) provide a clear indication of the operators' willingness to pay for spectrum. Our analysis of these data suggests a value in the range $23m-36m/MHz would be appropriate.

Recent auction prices for the 2.1 GHz band in high income countries could also provide a good guide to values in Hong Kong (see Figure 1-1). The average value from these auctions equals $17m/MHz in 2016 prices[4].

Taking the two sets of evidence together we recommend a value of $20m/MHz is applied as an SUF for the RFR spectrum in the 2.1 GHz band.

[4] Assuming a population of 7m, PPP exchange rates and inflation of 3.5% p.a. from 2012 to 2016.

2 Service continuity

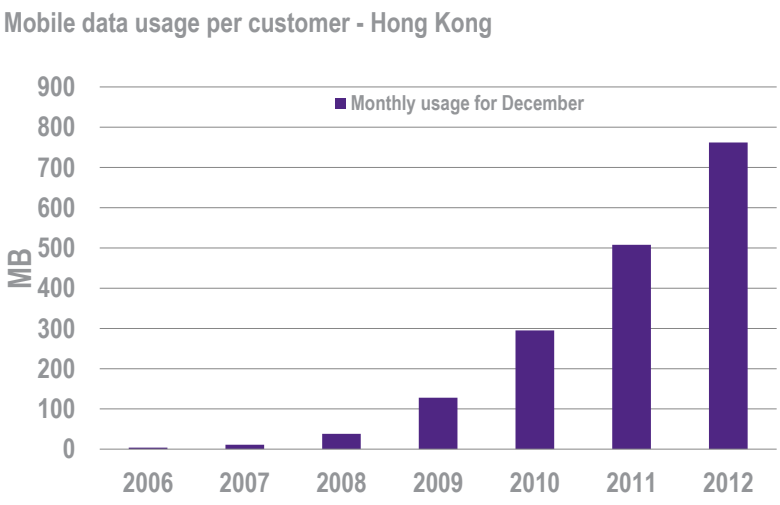
This section considers the effect of a reduction of spectrum assignments on service continuity, what it is likely to mean to consumers and disruptions costs that are likely to result. In doing this we take account of the fact that the market for mobile data services is not static; it is highly dynamic and any policy/regulatory changes to the market must be considered in the context of rapid growth in demand for mobile data.

2.1 Mobile data growth

In line with many other places in the world mobile data is growing rapidly in Hong Kong. OFCA's March 2012 consultation highlights that there was a **124%** increase in usage in 2011 with usage per customer increasing by **72%** to 509 megabytes per month. In its key statistics for wireless services[5], OFCA shows that mobile data traffic has continued to grow at a rapid pace with usage per customer in December 2012 being 761 megabytes per month (i.e. an increase of 50% within one year). The increase in usage has been driven in particular by the availability of smartphones and more recently tablets.

Although spectrum to support 3G data services has been available since the early 2000s most growth has occurred since 2008 when such devices became available in large volumes. Figure 2-1 shows mobile data usage in Hong Kong where the uplift since 2008 is clearly visible. Figure 2-2 shows the total number of iPhones, iPads and android devices sold globally to illustrate this point.

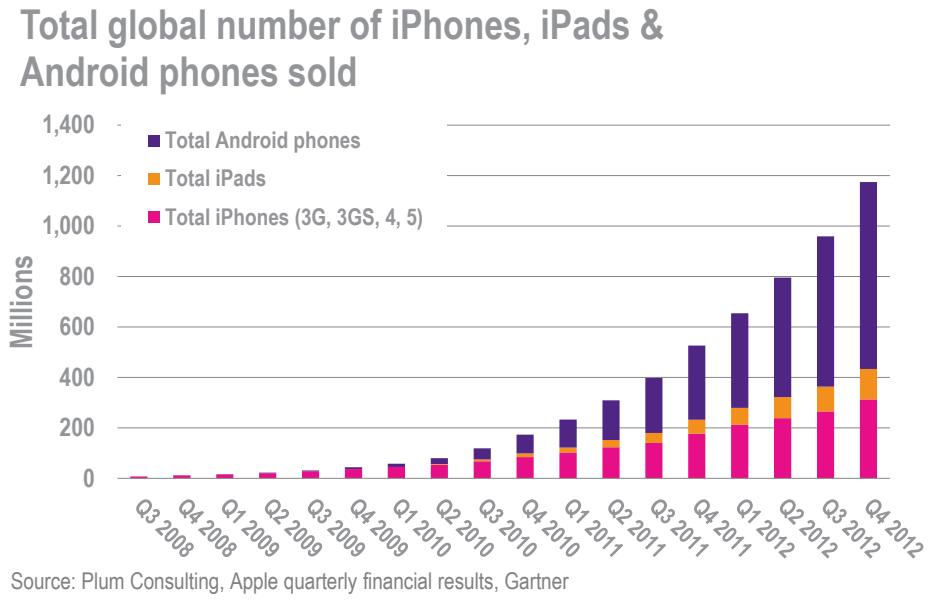
Figure 2-1: Mobile data usage in Hong Kong



Source: OFCA

[5] Key statistics for telecommunications services in Hong Kong: Wireless services, OFCA 7th March 2013

Figure 2-2: Sales of iPhones, iPads and Android phones



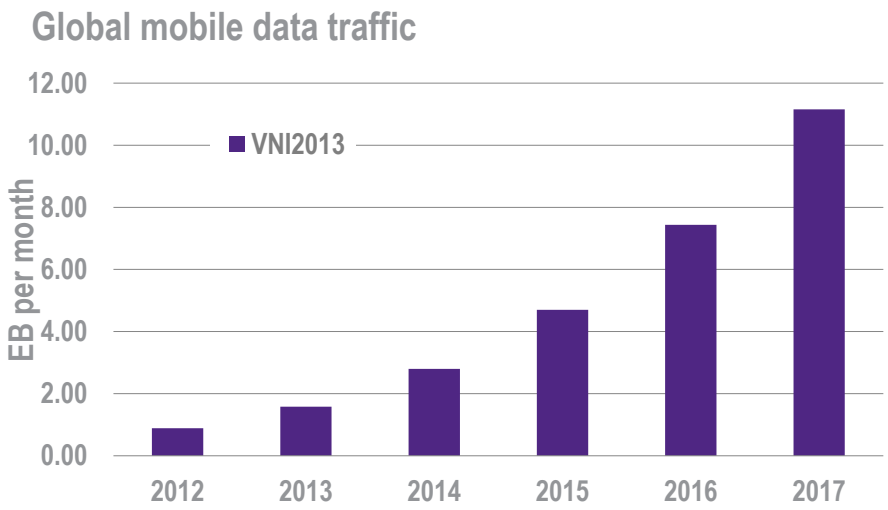
Source: Plum Consulting, Apple quarterly financial results, Gartner

Mobile data traffic is forecast to continue to grow strongly. Cisco, in their 2013 Visual Networking Index (VNI), clearly show this trend with their forecast that mobile data will grow at a Compound Annual Growth Rate (CAGR) of 66**%** globally up to 2017 as shown in Figure 2-3. This strongly suggests that any action which would create disruption, congestion or service degradation, including making significant rearrangements to 2.1 GHz spectrum on expiry of the existing assignments should be avoided to minimise potential disruption to growth of 3G data services.

Cisco forecasts that 55% of global mobile data traffic will still be carried on technologies other than 4G by 2017[6]. Hong Kong is a fast adopter of new technology and although we expect adoption of LTE services in Hong Kong between now and 2017 there remains a significant requirement for capacity provided by 3G/HSPA technology in this timeframe. It will also be necessary to retain 3G/HSPA data services for international roaming traffic.

[6] Cisco Visual Networking Index 2012 - 2017, February 6, 2013. "In 2017 4G will be 10% of connections but 45% of total traffic". http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

Figure 2-3: Cisco's global traffic forecast 2013



Source: Cisco

2.2 Adverse effects of spectrum reduction on service continuity

OFCA recognises that reducing the amount of spectrum available to an operator will impact the service continuity it provides for its customers. While certain measures can be taken to modify the network in an attempt to compensate for the reduction in spectrum these measures will require investment that is inefficient (i.e. costs of the investment outweigh the benefits). Further, none of these measures appear to be appropriate given the current status of 3G development in Hong Kong - cell splitting and other optimisation measures are already in widespread use in Hong Kong to provide more capacity in dense traffic areas. Even if these measures could be extended it is still not possible to guarantee that 3G network arrangements after 2016 will be able to cope with mobile data traffic growth and meet consumer demand in the face of a reduction of spectrum.

The effects likely to result from reducing the amount of an operator's 2.1 GHz spectrum are:

- Cell congestion due to inability to serve traffic demand – this will result in consumers not being able to establish voice calls / data sessions on demand, which will reduce the quality of service offered. It could also lead to calls / data sessions being dropped in cell or at the point of handover if no or insufficient resources are available in the adjacent cell.
- Reduced service availability due to interference that arises from less than optimal co-ordination – this will result in consumers experiencing temporary degradation/loss of service and this may be a significant problem while transition of network arrangements occurs.
- More difficulty in recovering from overload as it will take longer for the cell to re-establish available resources for handling voice calls / data sessions.
- An adverse effect on the service enjoyed by international roaming users given the use of 2.1 GHz for 3G services globally.
- An increase in consumer dissatisfaction and complaints.

All the above lead to a reduction in the quality of service delivered to consumers, which would be inconsistent with OFCA's and the Commerce and Economic Bureau's statutory objectives and stated mission[7]. Therefore Option 3 appears unlikely to satisfy relevant criteria on the treatment of 2.1 GHz spectrum as compared to Option 1.

2.3 Disruption costs

Disruption costs that arise from adoption of Option 3 (and not Option 1) are those associated with:

- Changes in network service coverage and potential lack of service during transfer to a new provider.
- Changes in service quality.
- Enforced customer churn.
- Enforced change of handset by consumers.
- Higher prices if operators incur significant costs in retuning or otherwise adjusting their networks.

Looking specifically at the change in network service coverage, these costs could be substantial and include investment in the same or other bands to maintain quality of service.

Reducing the 2.1 GHz spectrum available to 3G mobile operators will decrease network capacity and efficiency. This may be alleviated to some extent by modifying the network but there will be practical constraints on the extent of modification possible in Hong Kong (e.g. due to the limitations of providing new base stations in densely built up areas, gaining access to land/property at reasonable cost, implementing backhaul arrangements using microwave) . However, these network modifications come at a significant cost.

The total traffic throughput of a 3G base station depends on the amount of spectrum assigned. In a 3G network, this becomes more important because the implementations of 3G/HSPA use a carrier size of 5MHz. Although the standards support sub 5 MHz carriers in reality this aspect of the standard has not been implemented in most network equipment. Therefore, it is not possible in practice to incrementally add smaller bandwidths of less than 5 MHz of other spectrum compatible with 3G (e.g. 900 MHz) to increase capacity. This means that without significant network modification there will be at least a one-third reduction in network capacity if an operator's holding is reduced from 2 X15 MHz to 2 X10 MHz.

The result is that the network becomes saturated with data traffic more quickly and/or in more areas during high-usage periods. As a result there will be a lower average data throughput and hence a lower quality of service for all users.

OFCA bases it proposal to adopt Option 3 on the analysis in Annex 2 of its second consultation. This analysis is flawed for the following reasons:

- Annex 2 focuses on download speed whereas the key factor for meeting demand is the capacity or data throughput of the network. A high capacity network is achieved by a combination of the amount of spectrum available and the reuse of spectrum (determined by network layout). Consideration of download speed alone is not sufficient.

[7] See paragraph 16 of the March 2012 consultation

- The analysis assumes the status quo in terms of the number of operators when it introduces spectrum in bands other than 2.1 GHz into its analysis. This is clearly not a realistic basis on which to perform the assessment. New entry has occurred with previous releases of spectrum (see Figure 3-1 below).
- It makes an assumption that 3G and 4G carriers are equivalent entities – they are not. 3G carriers are usually fixed at 5 MHz whereas for LTE it is more likely that equipment will support a range of carrier bandwidths from less than 5 MHz to 20 MHz or more with LTE Advanced. Also, 3G and LTE technologies differ in terms of bits/Hz performance, which means that they may not offer equivalent data throughput on equivalent carrier bandwidth.
- Paragraph 8 states that latest technology available and expansion/addition of cell sites would effectively double the network capacity. No breakdown is provided of the specific measures OFCA has in mind nor the relative contribution of each of these factors to the overall improvement in network capacity.
  - We understand that the 3G licensees have already implemented the latest HSPA technology (i.e. dual carrier 42 Mbps). Therefore any further increase in the capacity of the network would have to come from further cell splitting and small cell deployment, techniques that are already being extensively used by mobile operators in Hong Kong. It is therefore difficult to see how an effective doubling of network capacity could be achieved. In any case, any additional or incremental benefit conferred by the application of such measures would be marginal.

A summary of measures to increase network capacity is shown in Table 2-1. All three methods involve substantial costs, disruption and uncertainty. At the very least, there is new network capital expenditure (CAPEX) associated with additional radio access network components and the network-planning required for implementation. Adoption of these measures could also increase the likelihood of network interference. The measures to increase network capacity are described in more detail at Appendix A.

Table 2-1: Measures to offset capacity loss

Measure	Description	Consequences
Using additional spectrum in other bands	Use a 5 MHz pair from a different frequency band to increase capacity	Needs new equipment/antenna at base station Additional capex Customer migration costs
Cell splitting	Reduce coverage area of base stations and insert new base stations to fill the gaps and provide additional capacity	Re-plan the network Raises base station count Additional network capex Additional opex for new base stations
Use of a microcell layer	Create an overlay of small base stations focused on traffic hotspots	Re-plan the network Raises base station count Additional network capex Additional opex for microcells

2.4 Support for multi-carrier HSPA

Operators in Hong Kong already make use of the multi-carrier capability of HSPA technology. This enables the support of 42 Mb/s with the use of two carriers.[8] The use of such technology enhances the bandwidth available to consumers enabling higher data rate applications (e.g. higher quality video streams). Reducing the number of carriers available per operator at 2.1 GHz reduces the opportunity to deploy future multi-carrier solutions (e.g. three carriers solution if option 1 is adopted) and it will limit the scope and quality of services available to consumers with sophisticated 3G terminals (e.g. higher end smartphones and tablets). It is doubtful that operators would continue to deploy such solutions if there is uncertainty caused by the adoption of policy options that potentially reduce the spectrum available to each operator.

2.5 Situations with special technical arrangements

We are aware that the provision of 3G services on the Hong Kong MTR and in other indoor high usage locations is enabled by specially designed equipment built to operate at specific frequencies. In the event of an operator's frequencies being changed there is likely to be a specific disruption cost brought about by the need to redesign and re-equip the antenna systems and other special equipment used in these locations. This situation is aggravated as any required changes to the MTR systems will take longer than those to other indoor systems given that time granted to mobile operators each day to implement changes, carry out testing and perform maintenance is very limited.

2.6 Conclusion

The adoption of Option 3 is being considered against a backdrop of significant growth in demand for mobile data services (Cisco forecast that mobile data traffic will grow by a factor of 12 globally between 2012 and 2017). While by 2017 4G/LTE technology will be growing, Cisco forecast that 55% of mobile data traffic (globally) will be carried by non 4G technology (e.g 3G/HSPA). Although Hong Kong is a fast adopter of new technology and some users will have adopted LTE services by 2017 there remains a significant requirement for capacity provided by 3G/HSPA technology with such strong mobile traffic growth. It will also be necessary to retain 3G/HSPA data services for international roaming traffic.

Disruption to the delivery of 3G/HSPA services through a reduction in the amount of spectrum available to operators in this timeframe will cause significant harm to consumer services resulting from:

- A degradation in quality of service through a reduction in capacity
- Adverse effects on roaming for international users
- An increase in consumer dissatisfaction and complaints
- Increased industry costs and inefficient investment.

[8] Future 3gpp releases will support three or more carrier capability that would support data rates of 63 Mbps and higher. A 3G operator limited to two 5 MHz carriers in the 2.1 GHz band would have to use carriers from other spectrum bands to support multi carrier functionality requiring more than two carriers.

3 Stated benefits from re-assigning spectrum via auction

OFCA states that the possible benefits of releasing some of the 2.1 GHz band through auction include:

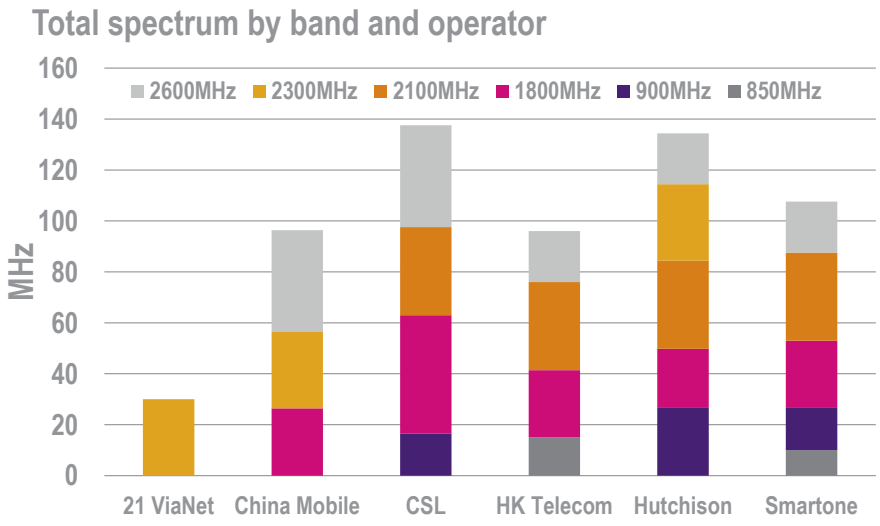
- Greater efficiency of spectrum use resulting from a reassignment of spectrum
- Increased competitive pressure and the innovation/investment benefits that flow from new entry.

Below we examine the availability of spectrum in Hong Kong, efficiency and the implications of Options 1 and 3 for competition and innovation.

3.1 Current spectrum holdings

In addition to the four incumbent 3G mobile operators there are two other operators in Hong Kong with substantial spectrum holdings suitable for supporting LTE. The overall spectrum holdings for all operators are shown in Figure 3-1. These holdings provide the opportunity for further competition for mobile data services in Hong Kong. The potential competition provided by the use of this spectrum together with the new spectrum to be released from 2013 onward will act as an additional competitive spur to the incumbent 3G operators.

Figure 3-1: Spectrum holdings



Source: Plum Consulting

3.2 Efficiency

The development of mobile services in Hong Kong, the intense competition and the growth in mobile data traffic all suggest that the usage of 3G spectrum in Hong Kong is efficient. If OFCA has doubts in this regard it should examine the current utilisation of 2.1 GHz spectrum and how this will change in the period to 2016 and beyond with mobile data traffic growth to reassure itself that the spectrum is being used efficiently.

We note that OFCA does not attempt to provide any information on the efficiency of current use of 2.1 GHz spectrum. In its March 2012 consultation document[9] OFCA states that "*there are no readily available concrete indicators to assess the efficiency of the incumbent operators in utilising the spectrum*". This assertion is based on OFCA's conclusion that "*It may be possible to attain higher spectral efficiency for the industry as a whole by varying the distribution of the spectrum among incumbent 3G operators or by recruiting new players to the 3G mobile service market.*" As no hard data has been presented by OFCA we are sceptical of the analysis presented in the consultation.

However, there are some basic indicators that can be used to assess how efficiently spectrum is being used including:

- The loading of 3G networks
- The extent of deployment of the most advanced technical techniques (e.g. HSPA+)
- The number of 3G carriers deployed.

In all cases the higher the value of the measure the greater the technical efficiency of spectrum use. Without some assessment based on such measures it is not possible to determine whether spectrum is being efficiently used or not and therefore whether higher efficiency could be achieved by varying the spectrum distribution among players.

The European Commission recently commissioned a study[10] on the potential for improving spectrum efficiency through use of a spectrum inventory. Inventory is seen as a key tool in the delivery of the European Union's Radio Spectrum Policy Programme (RSPP). It sets out to establish practical arrangements and uniform formats to determine the effective use of radio spectrum. A significant part of the output is a methodology that examines how efficiently spectrum is being utilised based on:

- Utilisation
- Demand trends
- Technology use
- Population coverage.

Without a more thorough analysis based on firm evidence it is difficult to reach any concrete conclusions on the efficient use of 2.1 GHz spectrum other than that the fierce competition for mobile services in Hong Kong suggests that spectrum use is efficient.

3.3 Competition and innovation

Below we examine the implications of Option 1 and 3 for competition and innovation. In particular:

- In assessing whether Option 1 or 3 should be adopted, OFCA should consider the additional costs and benefits that one option offers versus the other option. This has not been done in OFCA's published analysis.

[9] See Paragraphs 20, 21 and 47

[10] Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency. WIK, Aegis Systems Idate and Plum 2012 http://www.plumconsulting.co.uk/publications

- When looking at the additional benefits arising from re-auctioning assigned spectrum (Option 3), these seem likely to be relatively small (if they arise at all) given the already highly competitive and dynamic mobile market in Hong Kong. In any event the benefits are likely to be outweighed by the costs involved.
- Additional monetary and non-monetary costs seem substantial in the short-term from an end-user's perspective as well as for the industry. These are related to potential lack of coverage, service disruption, poor quality of service and increased OPEX and CAPEX.
- High levels of innovation and competition (and end user benefits) are characteristic of the Hong Kong market. Both 2.5/2.6 GHz and digital dividend spectrum are bands in which LTE technology will be deployed. With six operators already holding LTE capable spectrum in Hong Kong, competition in these bands will be intense by 2016.
- The auction of 50 MHz of 2.5/2.6 GHz spectrum has taken place in March 2013 and further spectrum is expected to be released in perhaps 2015 (see Figure 3-2). This will enable new entrants to enter the market and incumbent operators to flexibly readjust their spectrum holdings in line with the evolution of technology and market conditions.
- MVNO arrangements also enable new operators or operators without 3G spectrum to compete effectively in the 3G market with the incumbent spectrum holders. In particular, it is understood that China Mobile has already established MVNO arrangements with two of the incumbent 3G operators.
- In addition to the points above, OFCA should focus on introducing spectrum trading as stated in their 2009 study and in line with their 2013 projects plan. In an environment where market-based mechanisms are introduced, operators will be capable of addressing their spectrum needs without any regulatory intervention and to invest efficiently. Intrusive regulatory intervention to re-auction a small amount of spectrum which has been used efficiently would then be redundant or harmful as it could create uncertainty and ultimately delay efficient investment.

Figure 3-2: Spectrum release in Hong Kong

Source: OFCA

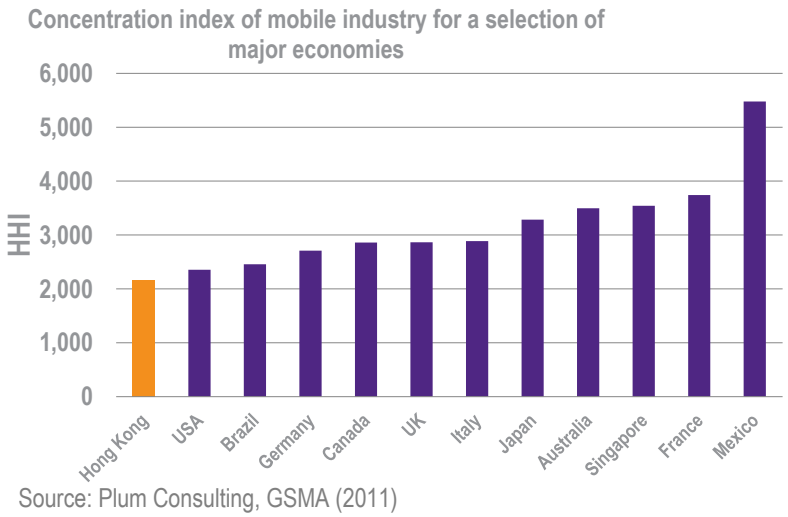
3.4 A high-level cost benefit assessment

In order to assess which is the most appropriate policy option we compare the potential benefits and costs of Option 3 to Option 1. One of the potential benefits that OFCA asserts for Option 3 is more competition. OFCA maintains that new players may be at the forefront of service innovations or working on new business paradigms, thereby inducing even keener competition particularly in the

market for mobile broadband services. However, OFCA does not clearly set out what the innovations or new business paradigms might be, or the criteria against which these would be assessed. This is also against a backdrop of Hong Kong's mobile market, which OFCA acknowledges is already one of the most developed and competitive in the world:

- With one of the highest levels of mobile penetration with OFCA reporting a penetration of 228.6%[11].
- Penetration has kept rising over the past year, as OFCA's official figures report. Connections have now gone beyond 16 million in December 2012, of which over 9 million connections are reported to be 3G/4G customers[12].
- The market exhibits healthy competition with the five main players all having a market share above 10% and with the lowest concentration index (Hirschman Herfindall index) among all major economies (see Figure 3-3).

Figure 3-3: Mobile industry HHI



Source: Plum Consulting, GSMA (2011)

OFCA states that new market entry as a result of spectrum being released in the 2.1GHz band may stimulate further competition resulting in more diversified offerings for specific services or segments. It may deliver innovation to consumers earlier, to the benefits of citizens and business. Even if that is the case (and that is highly speculative as a loss of spectrum may also lessen competitive forces), in an environment that is already as competitive as Hong Kong any gain beyond the existing competitive conditions would probably be marginal.

Conversely an examination of additional costs to society associated with the awarding of 3G spectrum to new entrants in what would be a spectrum zero sum game includes:

- Changes in service and quality
- Enforced consumer churn
- Change of handsets.

[11] OFCA: Key Communication Statistics – mobile penetration rate (December 2012)

[12] OFCA: Key Statistics for Telecommunications in Hong Kong – Wireless Services (07.03.2013)

We have discussed in Section 2 the negative effects of disruption, which creates a cost for the existing players and the whole mobile industry (and users), both in terms of higher OPEX and CAPEX for network restructuring, re-tuning and upgrades as well as increasing customer retention costs. From the consumer perspective, network disruption may cause both consumers and business to be dissatisfied.

Table 3-1 summarises a high level and qualitative cost-benefit analysis of the impact of Option 3 versus Option 1. Even in the event that further competition generates marginal benefits to end-users it is likely that this will be outweighed by the disruption costs arising from the partial exit from 2.1 GHz spectrum by one or more of the incumbent 3G operators.

Table 3-1: High level cost-benefit analysis for Option 3 versus Option 1

Additional benefits	Likely Additional costs
• More diversified offering (possible) • Lower prices (unlikely) • More innovation in the market (unlikely)	• Poorer service availability (possible) • Lower service quality: calls/data sessions dropping; poor service at peak hours (likely) • Increased OPEX and CAPEX for network upgrades and customer retention (likely) • Handsets replacements (possible) • Poor quality of international roaming (possible)

Given the uncertain nature of benefits arising from the re-auction of 2.1 GHz spectrum, it is crucial that any decision to adopt Option 3 is backed up by a rigorous economic impact assessment. We have proposed a structure for proper economic impact assessment in Appendix C.

A robust economic impact assessment should consider all the potential outcomes from an auction of 2.1 GHz spectrum and both costs and benefits should be quantified for each outcome. Any partial analysis that does not closely match real and quantifiable benefits with all the corresponding costs will introduce bias into the decision making process and risk regulatory failure.

4 International experience of direct renewal/right of first refusal

A review of international experience shows that the option recommended in this report for Hong Kong – direct renewal/right of first refusal – is well-established in other jurisdictions for comparable situations. Indeed some jurisdictions which, like Hong Kong, have advanced telecommunications markets apply a presumption of renewal, i.e. licences will be automatically renewed to the incumbents unless there is clear evidence of inefficient spectrum use, lack of competition or persistent licence contraventions (none of which apply in Hong Kong).

Since spectrum licences for 3G were mostly issued in the early 2000s and onwards, and as the licence duration is typically 15-20 years, there are not many examples of treatment of expiring 2.1 GHz spectrum. Therefore, the summary below includes the treatment of expiring 2G spectrum (900 MHz, 1800 MHz). The same policy considerations (i.e. service continuity, promotion of effective competition, efficient spectrum utilisation and encouragement of investment and innovative services) should, nevertheless, apply equally to the renewal of 2.1 GHz spectrum.

Direct renewal/right of first refusal has been used successfully in a number of places including Hong Kong, Australia, Portugal, New Zealand and Singapore. An extension of this approach is the presumption of renewal seen in countries with more developed spectrum regimes, particularly where spectrum trading is a realistic option. Examples here include Canada, the USA and the UK. Although there has been discussion of spectrum trading in Hong Kong it has yet to become a reality.

Direct renewal/right of first refusal is often used for the renewal of assignments in respect of spectrum bands which are, as in the current Hong Kong context, already utilised. Examples of its successful application are listed below.

- In the UK Ofcom has adopted a policy of presumption of renewal for spectrum currently held by operators at 900 MHz and 1800 MHz. The licences have recently been renewed in perpetuity. A new annual licence fee will be set for these licences in 2013.
- In February 2012 the Australian government decided to reissue the expiring 15-year licences for the various frequency bands, including 850 MHz and 1800 MHz, to incumbent operators (Telstra, Optus, Vodafone).[13]
- A similar approach was also used in Singapore for the renewal of 2G spectrum (900, 1800 MHz) in 2008. Existing licence holders (M1, SingTel, StarHub) were granted the right of first refusal for each lot, and because no more than one offer was made for each lot, the IDA awarded a total of 2x30 MHz to each incumbent operator.[14]
- In 2003, the New Zealand government adopted a policy of reallocation upon expiry to existing rights holders, although each case is subject to a case-by-case review.[15] In 2007 renewal offers for 850 and 900 MHz spectrum were made to incumbents Telecom NZ and Vodafone on condition that they each complete a secondary market sale of at least 2x5 MHz to a new entrant (Two Degrees). Two Degrees subsequently renewed the 900 MHz spectrum gained from that sale in 2011. All 850 and 900 MHz licences now expire in 2031.

[13] http://www.dbcde.gov.au/radio/radiofrequency_spectrum/spectrumlicences

[14] http://www.ida.gov.sg/Policies-and-Regulations/Industry-and-Licensees/Spectrum-Management/Spectrum-Rights-Auctions-and-Assignment/PCMTS-Spectrum-Rights-Auction.aspx#.ULdxUeSpCuk

[15] http://www.rsm.govt.nz/cms/policy-and-planning/projects/recently-completed-work/cellular-rights

- In 2006, the Portuguese regulator Anacom renewed Vodafone's expiring 2G licences (900, 1800 MHz) for 15 years until 2021 following a request by Vodafone.[16] Subsequently in 2007 Anacom also renewed TMN's licence for a similar 15-year period.[17]

The same approach was used in Hong Kong:

- For the re-assignment of spectrum used for analogue mobile services to digital services
- For renewal of expiring 2G spectrum.

[16] http://www.anacom.pt/render.jsp?contentId=340266

[17] http://www.anacom.pt/render.jsp?contentId=561950

5 Setting an SUF

5.1 OFCA's proposals

The Hong Kong Spectrum Policy Framework states that the spectrum utilisation fee (SUF) may be set to reflect the opportunity costs of the spectrum[18]. Regulators elsewhere in the world have also set spectrum prices for spectrum used by mobile operators and other services to reflect opportunity costs, on the grounds that this promotes economically efficient spectrum use[19]. Opportunity cost based prices are prices that would result from a competitive market. This is noted by OFCA in its first consultation where it sets out the following high level principles for setting an SUF[20]:

> *"In offering the right of first refusal to the incumbent 3G operators, the TA has to set the SUF that would reflect as far as possible the full market value of the spectrum, i.e. a level of SUF as if it would have been determined through market means although the market does not actually exist on this occasion."*

Market prices are usually revealed through spectrum trades or auctions and so benchmarks from auctions held in Hong Kong and elsewhere are relevant to deriving an SUF for 2.1 GHz spectrum.

In the first consultation OFCA asks for views on four broad approaches to setting an SUF for the right of first refusal (RFR) spectrum:

- Directly calculated values – the least cost alternative (LCA) method (under Options 1 or 3)
- Market benchmarks *including* specifically the results of the auction of 50MHz of paired spectrum in the 2.5/2.6GHz band[21] (under Options 1 and 3)
- Conducting a "mock" auction to determine the SUF (under Option 1)
- Set the SUF based on the average price paid for spectrum re-auctioned (under Option 3).

In the second consultation OFCA evaluates these four options and reaches the following conclusions:

- It rejects the mock auction approach on the grounds that this would not be a genuine auction and as such could be subject to manipulation by either new entrants or incumbents[22].
- It rejects use of directly calculated values based on LCA on the grounds that these would be too subjective being based on numerous assumptions about future market and technology developments[23].
- It rejects setting the SUF based only on the average price of the spectrum re-auctioned. OFCA noted that this was risky for incumbents "*as they would need to decide whether to exercise the RFR before knowing the actual amount of SUF to be paid*"[24].

[18] Para 7.2 http://www.cedb.gov.hk/ctb/eng/legco/pdf/spectrum.pdf

[19] See the examples of Australia, New Zealand and the UK given in Appendix B.

[20] para 25,Arrangements for the frequency spectrum in the 1.9-2.2 GHz band upon expiry of the existing frequency assignments for 3G mobile services, Consultation Paper, OFCA, March 2012.

[21] See para 31, op cit.

[22] Para 41, Second consultation paper, December 2012.

[23] Para 42, op cit.

[24] Para 43, op cit.

In the second consultation OFCA makes two further proposals for setting the SUF for renewed spectrum licences under Option 3. These proposals are based on market benchmark information for Hong Kong and the average price of the re-auctioned 2.1 GHz spectrum and are as follows:

i. SUF/MHz = max ($77m, auction price[25]), where $77m is derived by taking the annual SUF in 2015/16 under the current licences and multiplying this by 15 – the duration of the renewed 2.1 GHz licences.
ii. SUF/MHz = average($80m, auction price), where $80m is derived by taking a weighted average of past auction prices in Hong Kong with more weight given to the 850/900MHz auction than the wireless broadband spectrum auction results (i.e. auction of the 2.5/2.6 GHz band). The weights used by OFCA are not disclosed (which makes this a "black box" proposal).

There are no specific proposals for an SUF for Option 1. However, as no auction occurs under Option 1 it might be inferred from the proposals given above that OFCA would set the SUF under Option 1 at $77m/MHz to $80m/MHz. This is assumed below in our discussion of OFCA's new proposals.

5.2 OFCA's proposed values are too high

OFCA's current proposals rely in part on the use of historic market benchmarks to determine the 2.1 GHz SUF. These benchmarks include variously the results of past spectrum auctions for other frequency bands and the 2015/16 payments for the 2.1GHz band (which were determined by a royalty auction). OFCA's proposed values of $77m/MHz and $80m/MHz are much greater than recent international auction values for the 2.1 GHz band in high income countries[26] when put on a comparable basis i.e. adjusted for differences in population and the amount of spectrum sold, converted to Hong Kong dollars and adjusted to 2012 prices.[27] This can be seen in Figure 5-1.

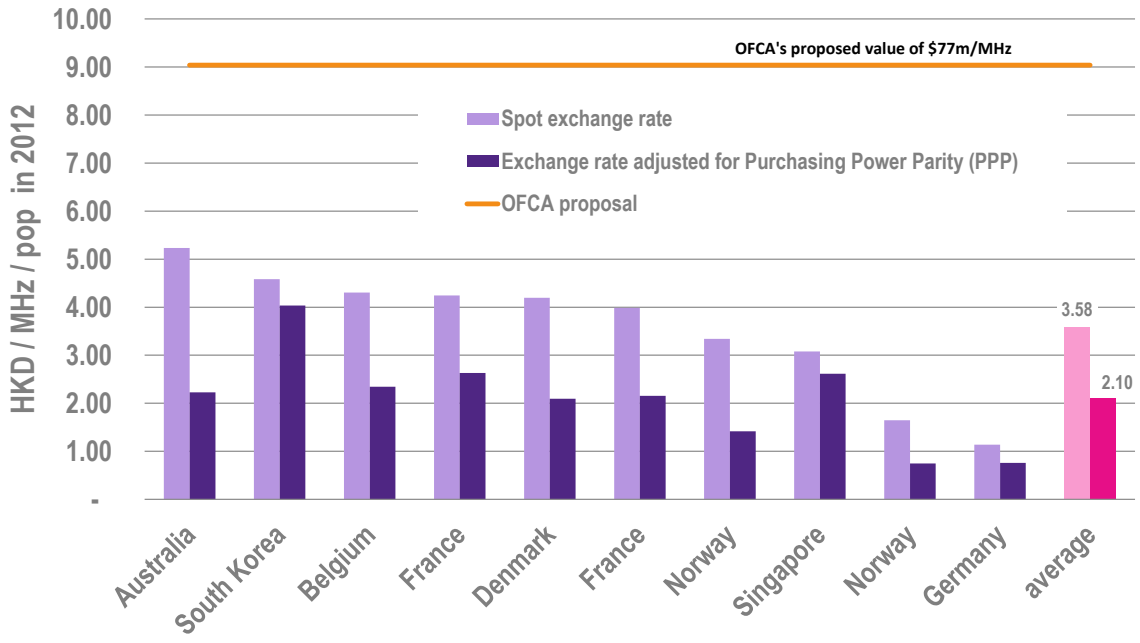
The data reported in Figure 5-1 show values/MHz/pop obtained using both spot and PPP exchange rates. PPP exchange rates arguably provide a more accurate reflection of a currency's true value than spot exchange rates because they reflect the purchasing power of the currency and remove the effect of short term fluctuations driven by non-economic factors (e.g. short term perceptions of political risk). The values based on PPP exchange rates indicate that OFCA's proposals are over four times the average implied by the international benchmarks.

[25] Para 57 of the first consultation indicates that the auction price will be the average price/MHz from the proposed auction.

[26] The results of auctions in high income countries since the start of 2005 (i.e. Belgium, Denmark, France, Germany, Norway, Singapore, South Korea) and the Australian spectrum renewal price are reported.

[27] To ensure comparability with Hong Kong, we have normalised the value/MHz/pop of the international auctions to reflect a 15 year licence term. The adjustment is based on the NPV calculation of licence value using a WACC of 7%. High income countries are as defined by the World Bank.

Figure 5-1: Value/MHz/pop of 2.1 GHz auctions in high income countries



Note: Values have been normalised to 15 year licence duration.
Source: Plum Consulting, Regulators' websites

It is clear that the values set by OFCA are far too high. In the analysis given below we also show there are flaws in the way OFCA has derived values from Hong Kong market benchmarks that result in values that are too high. In particular:

- OFCA has not taken account of the need to discount future values to give a lump sum value for the SUF in 2016.
- OFCA has not recognised that the final year payment for the 2.1 GHz licences is likely to overstate the annual value of spectrum over the current licence period. The final year payment is the last in a series of steadily increasing SUFs set at the time of the auction in 2001. There is no evidence values are increasing over time (in nominal or real terms) and so this value cannot be said to provide a good indicator of future value or be representative of the average SUF paid over the licence period.
- OFCA has not taken account of the fact that the 3G operators were awarded 5MHz of TDD spectrum, as well as the FDD blocks, in 2001.
- OFCA has not taken due account of the characteristics of different frequency bands when using historic Hong Kong benchmarks and so has overestimated the value of the 2.1GHz band.

Furthermore OFCA has not taken into account relevant international benchmark values.

The net result is that OFCA's estimates of the value of the 2.1 GHz band are more than double the value justified by either the current 2.1 GHz payment schedule and up to four times the relevant international benchmarks.

5.2.1 Deficiencies in OFCA's derivation of the $77m/MHz value

OFCA appears to have derived the $77m/MHz by:[28]

- Taking the annual payment per operator for the 2.1 GHz spectrum in 2015/16 of $151.243m and dividing it by the amount of paired spectrum held by each operator (i.e. 2x14.8) to give $5.1m/MHz.
- Multiplying this number by the duration of the licence – 15 years – to get $77m/MHz.

This calculation does not take into account the following factors:

- The operators purchased 2x14.8MHz paired **and** 1x5MHz unpaired spectrum, not just the paired spectrum.
- That payments for the 3G licences rose through the licence period at annual rates of between 7% and 20%. The original purpose of a rising fees schedule was to share risk between government and the operators, so the latter were not burdened with a large upfront payment for their licences. This means initial payments understate the annual spectrum value while later payments overstate its annual value.
- To derive a lump sum value from a stream of 15 annual values requires calculating the net present value of 15 annual values. The net present value is the sum of each annual value multiplied by a discount factor equal to 1/(1+WACC)**$^{N-1}$, where WACC is the nominal value of the weighted average cost of capital and N is the number of years from the start date and has values 1, 2, 3…15.

Taking account of TDD spectrum

When operators purchased 2.1 GHz spectrum in 2001 they expected the unpaired spectrum to have value but we do not know whether this value was equal to or more or less than the value of the paired spectrum. We have examined the results of 3G auctions in other countries where the FDD and TDD bands were sold separately and have found two examples giving quite different relative values:

- In the Austrian 3G auction (in November 2000) the paired and unpaired spectrum had almost equal values/MHz.
- In the Australian 3G auction (in March 2001) the unpaired spectrum had much less value - about 1/5th – than the paired spectrum[29].

We consider two extremes, one in which the unpaired spectrum is assumed to have zero value (OFCA's assumption) and one in which the unpaired and paired spectrum are assumed to be of equal value. The latter assumption has the effect of reducing the value/MHz by 14%.

An alternative to final year operator payments

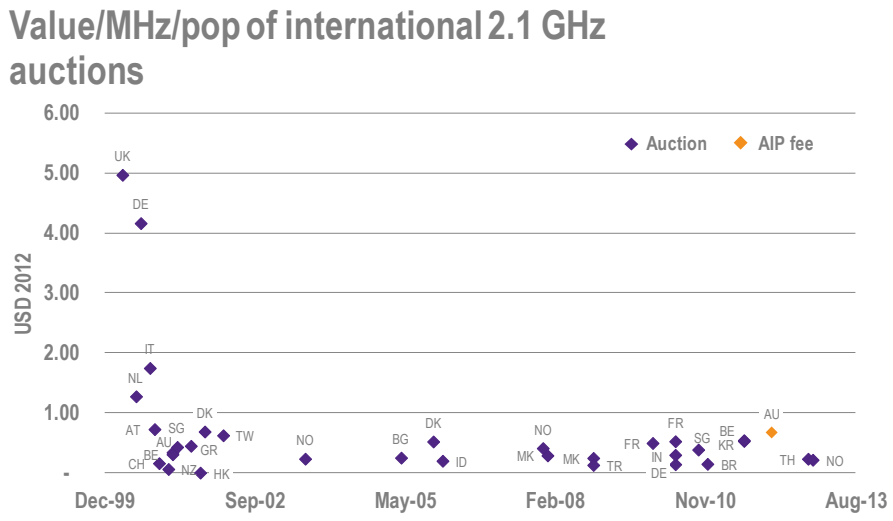
OFCA justifies the use of the year 15 value of $151m to derive a value for the next licence period on the grounds that future growth in mobile data traffic will result in an increase in the value of spectrum

[28] Para 58, Second consultation

[29] Using the relative values in Sydney (regional lots were auctioned).

over time. However there is no evidence from international auction results that spectrum values are rising in response to growth (actual or anticipated) in data traffic – see Figure 5-2. This is because the market price of spectrum depends on *supply* as well as demand factors.

Figure 5-2: Results of 2.1 GHz auctions and licence renewal fees (i.e. AIP[30] fee)



Note: Values have been normalised to 15 year licence duration.
Source: Plum Consulting, Regulators' websites

On the supply side, regulators around the world are seeking to support growth in mobile data traffic with an increasing supply of spectrum and this will have the effect of keeping prices down. Importantly there are targets to release additional spectrum for mobile broadband in Japan, Europe and the US – 1.5 GHz by 2020 in Japan[31], 800MHz by 2020 in the US[32] and 600MHz identified by 2015 in Europe[33] – which are intended to enable low cost delivery of services and improved service quality. To support these activities detailed spectrum audits are being conducted in these and other countries to identify specific bands for allocation to mobile broadband[34]. These bands will be harmonised for use on a regional or global basis and so many of them can be expected to come into use in Hong Kong. For these reasons the final year payment of $151.243m is not a good indicator of operators' willingness to pay for spectrum in 2016.

Two more reasonable alternatives calculating the total SUF in 2016 are:

[30] AIP stands for administrative incentive price and refers to fees set by regulators intended to reflect opportunity costs.

[31] http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/councilreport/pdf/101130_1.pdf

[32] See the National Broadband Plan 2010 http://www.broadband.gov/ and The NTIA 10 year plan for spectrum http://www.ntia.doc.gov/files/ntia/publications/tenyearplan_11152010.pdf

[33] Radio Spectrum Policy Programme (RSPP), Decision No 243/2012/EU, March 2012, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:081:0007:0017:EN:PDF

[34] Some of these initiatives are intended to identify bands for harmonisation at WRC-15 under Agenda item 1.1 which is to "Consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution COM6/8 (WRC-12)".

- To base future payments on a simple average value of payments under the current 3G licences adjusted for inflation (so as to give a value in 2016 prices)[35]. This has the effect of reducing the estimated annual SUF value for the next licence period from $5.1m/MHz to $3.5m/MHz. The total SUF value is then calculated as the net present value (NPV) of payments over 15 years. This results in total SUF values of $23-36m/MHz in 2016 prices assuming that only the paired spectrum is taken into account.
- The total value implied by the net present value of the current 3G licence payments adjusted for inflation (so as to give a value in 2016 prices). This requires an assumption about the nominal (pre tax) weighted cost of capital. Based on information supplied by operators we have assumed that the value lies between 6% and 11%. This results in total SUF values of $25-33m/MHz in 2016 prices assuming that only the paired spectrum is taken into account.

The two approaches result in similar ranges and we propose the simple average value of payments because it encompasses the latter range and is close in concept to OFCA's approach.

Impact of discounting to derive an estimate of future value

We have recalculated the spectrum value taking account of the need to discount future values to obtain a lump sum value for the SUF for the 15 year licence period. The results are as shown in Table 5-1 together with OFCA's proposal of a value of $77m/MHz. Values are shown for the range of WACC values (6%-11%) and for two cases where paired and paired plus unpaired spectrum is used to convert the existing licence payments to a payment/MHz.

Discounting OFCA's value reduces the estimated value of the licences by 31-47%. A further 14% reduction is warranted if the base value is derived taking account of the unpaired as well as the paired spectrum operators bought in the 2001 3G auction. If an average rather than a final year payment for existing licences is used then the values fall even further. We suggest that the values based on an annual value of $3.5m/MHz given in Table 5-1 should apply. Our calculations suggest OFCA should be using a benchmark value in the range $23-36m/MHz, say $30m/MHz and not $77m/MHz.

[35] This might also be discounted however the payment schedule is highly skewed with low values for the first five years of the licence that we consider discounting this schedule probably gives an underestimate of value. We inflate values using the actual CPI inflation rate up to the end of 2012 and then 3.5% thereafter as is assumed by OFCA.

Table 5-1: Lump sum value/MHz (NPV discounted to 2016, $m 2016 prices)

Annual value/MHz (2016 prices)	WACC = 6%		WACC = 11%		Lump sum value/MHz proposed by OFCA
	Assuming only paired spectrum	Assuming paired and unpaired spectrum	Assuming only paired spectrum	Assuming paired and unpaired spectrum	
$3.5m – our proposed value	36	31	28	23	Not applicable
$5.1m – OFCA's proposal annual value	53	45	41	35	77

Source: Plum calculations

5.2.2 Deficiencies in OFCA's derivation of the $80m/MHz value

OFCA states that it derives the $80m/MHz value based on a weighted average of the SUF calculated on the basis of the annual royalty payment for the 3G spectrum in 2015/16 and the SUF for the broadband wireless access spectrum, which we understand means the 2.5/2.6GHz band, and spectrum in the 850/900MHz band. These SUFs were determined by auction as follows:

- The 2015/16 payment for the 2 x 59.2MHz paired spectrum and 20MHz unpaired spectrum at 1.9-2.1GHz band that was auctioned in September 2001 – this gives a value of $77m/MHz (taking into account the 2 x 59.2MHz paired spectrum only).
- 90MHz at 2.6GHz was auctioned in January 2009 and had an average price of $17m/MHz.
- 10MHz at 850MHz was auctioned in March 2011 and had an average price of $88m/MHz[36].
- 10MHz at 900MHz was auctioned in March 2011 and had an average price of $108m/MHz.

The weights used by OFCA are not published but it states that it has adjusted these values by average inflation rate of 3.5% since the time of the auction to give a 2016 value. It is our view that OFCA's choice of auctions and the relative weights biases outcomes towards a high spectrum value.

First, OFCA ignores:

- The results of the auction of 90MHz of 2.3 GHz spectrum in February 2012 which had an average price of $5m/MHz.
- The results of the auction of three blocks of 2 x1.6 MHz of 1800MHz spectrum in June 2009 which had an average one off upfront price of $4.8m/MHz and payments of $145/kHz in 2009, 10 and 11 and $1,450/kHz from 2012 to 2021[37].

Both these results should be considered given the frequency bands are very close to the 2.1 GHz band i.e. have similar propagation characteristics. Although we do recognise that the widespread use of the 2.1 GHz band around the world makes it more attractive than the 2.3 GHz (or the 2.6 GHz band) because of the low cost and widespread availability of handsets, this is not the case for the 1.8 GHz band. This is a global band for which low cost 2G and 4G devices are available.

[36] http://tel_archives.ofca.gov.hk/en/industry/850/p_success_bidding.pdf

[37] http://tel_archives.ofca.gov.hk/en/industry/1800/psbn.pdf See paragraph 3.

Second, OFCA gives a greater weight to the 850/900MHz as compared with the 2.5/2.6GHz auction results despite the fact that the characteristics of the 850/900MHz band differ considerably from the 2.1 GHz band. In particular:

- The 850/900MHz band gives much better coverage in buildings and in rural areas than frequencies above 1GHz. Moving from 900 MHz to 2.1 GHz results in roughly a halving of the coverage area from a base station (see Table 5-2). This increases demand for the 850/900 MHz frequencies and means it has higher value than frequencies above 1GHz - value is derived from *both* the coverage offered and the capacity of the bands.
- Much less bandwidth is available in bands below 1GHz as compared with higher frequency bands – the 850 MHz and 900 MHz bands together amount to 2x35 MHz which is less than the 2x60MHz at 2.1 GHz and the even greater bandwidths in the 2.3 GHz (90 MHz) and the 2.6 GHz bands (2x70 MHz). Hence there tends to be more vigorous competition for the lower frequencies and so higher prices.

Table 5-2: Node-B coverage areas (km^2) by frequency band

	Dense urban	Urban	Suburban	Rural
900 MHz	2.06	5.15	23.47	304.87
2100 MHz	1.1	3.57	14.65	139.06

Source: Ovum, Market study for UMTS900: A Report to the GSMA, February 2007

The combination of higher demand and less supply inevitably pushes up the relative price of frequencies below 1 GHz versus those above 1 GHz. In broad terms frequencies below 1 GHz are sold at prices roughly double those obtained at 1800MHz and 2.1 GHz. This can be seen in the average values of auction prices for high income countries since 2005 and in the reserve prices for some recent multi-band auctions held in Europe[38](shown in Figure 5-3). Spectrum prices for frequencies below 1 GHz should not therefore be used to set prices at 2.1 GHz.

Figure 5-3:

[38] Auctions included were those where at least the 800MHz and at least two other frequency bands were auctioned simultaneously i.e. the Czech Republic, Ireland, Italy, Netherlands, Portugal, Spain, Switzerland and UK.

Furthermore the recent Hong Kong 850MHz and 900MHz prices of $HK13-16/MHz/pop (in 2012 prices) are very high even for these frequency ranges when compared with international averages:

- The average value of 800MHz band from auctions in Europe is around $HK6/MHz/pop (from results for Denmark, France, Germany, Italy, Portugal, Spain, Sweden and the UK)
- The average value of the 850MHz and 900MHz auctions around the world (excluding auctions in Hong Kong) is $HK4/MHz/pop (from auctions in Denmark, Greece, Portugal, Singapore, South Korea, and Spain, and a licence renewal in Australia).

In short values based on the 850/900MHz band results will overstate the value of the 2.1 GHz band. For this reason the price of $80m/MHz derived by OFCA is too high. We present an alternative proposal in Section 5.4.

5.3 The SUF for RFR spectrum under Option 3

If Option 3 is adopted then OFCA proposes to use the results of auctioning around 2x20MHz of 2.1 GHz spectrum in setting the SUF (together with the historically determined benchmarks). There are two potential problems with doing this:

- Incumbent operators do not know the payment for the RFR spectrum when they bid for auctioned spectrum. This uncertainty is not desirable as it may result in inefficient bidding behaviour.
- Incumbent operators' bids for spectrum at auction will potentially be distorted by the impact on their payments for RFR spectrum. In particular, they will have an incentive to reduce their bids and there is then a risk of an inefficient auction outcome.

OFCA noted the first issue[39] in the second consultation and we assume this is why it abandoned its proposal to set the SUF solely on the basis of the average price of the re-auctioned spectrum.

OFCA recognised the second issue when it decided *not* to take account of the March 2013 2.5/2.6GHz auction results in deriving the $80m/MHz value. This decision was made on the grounds that taking account of the 2.5/2.6GHz auction result in setting the 2.1 GHz SUF could result in strategic bidding behaviour that would distort the 2.5/2.6GHz auction outcome. This very same concern over strategic bidding exists if the 2.1 GHz auction result is used to set the 2.1 GHz SUF under Option 3, and yet this forms an integral part of OFCA's proposals. OFCA's contradictory position here needs to be rectified by not using the 2.1 GHz auction results to set the RFR spectrum SUF.

These issues were recently addressed by Ofcom in the UK when considering how to set renewal prices for 900 and 1800MHz licences. Ofcom considered whether there should be a mechanistic link (e.g. a formula) that linked the renewal prices to the auction of 800MHz and 2.5/2.6 GHz licences (the discussion on renewal prices is currently on-going). Ofcom's analysis showed that there is a risk that RFR operators would rationally reduce their bids because of the impact on the SUF. While this risk can be reduced by setting a high reserve price the risk remains. Hence Ofcom concluded that there should not be a mechanistic link between auction prices and annual licence fees for 900 MHz and 1800MHz spectrum. By contrast OFCA's two proposals contain mechanistic links between the auction price and the SUF. This potentially risks distorting the 2.1 GHz auction as proposed under Option 3.

[39] Para 44, Second consultation.

We conclude that for Option 3 OFCA should **not** use the 2.1 GHz auction price to determine the SUF for the RFR spectrum for the same reason given by OFCA for not using the 2.5/2.6GHz auction results to determine an SUF i.e. that it could result in strategic bidding behaviour that would distort the auction. To avoid this outcome and to give all parties (incumbents and other bidders) certainty we consider that the SUF for RFR spectrum should be set independently of the 2.1 GHz auction[40]. Our proposal for doing this is given below.

5.4 Proposed SUF value for the RFR spectrum

To provide certainty and not distort the 2.1 GHz auction under Option 3, we consider that OFCA should set an SUF for the RFR spectrum in advance.

Regulators elsewhere have made use of international benchmarks to inform their view of the market value of spectrum and to set reserve prices in auctions (e.g. in Australia, Greece, Ireland, New Zealand and the UK). So which historic auction results give appropriate benchmarks for setting an SUF for the 2.1 GHz band?

Ideally we would use recent Hong Kong benchmarks; however, these apply to different bands with different characteristics from the 2.1 GHz and give a very wide range from $5m/MHz (2.3 GHz in 2012) to $108m/MHz (900 MHz in 2011). The 2.1 GHz market value should clearly fall within this range but where? The payments for the existing 3G licences (adjusted for inflation) provide a clear indication of the operators' willingness to pay for spectrum. Our analysis of these data suggests a value in the range $23m-36m/MHz would be appropriate.

Recent auction prices for the 2.1 GHz band in high income countries could also provide a good guide to values in Hong Kong. These values are reported in Figure 5-1. The average value from these auctions equals $17m/MHz in 2016 prices[41].

Taking the two sets of evidence together we recommend a value of $20m/MHz is applied as an SUF for the RFR spectrum in the 2.1 GHz band.

[40] Two recent examples in which there was both renewal and an auction are the 1800MHz band in Sweden and the 900MHz band in Greece. In both cases the regulator set the fee for RFR spectrum in advance

[41] Assuming a population of 7m, PPP exchange rates and inflation of 3.5% p.a. from 2012 to 2016.

Appendix A: Measures to offset loss of capacity

A.1 Additional spectrum in other frequency bands

The addition of more spectrum is the simplest way to increase the capacity of a saturated cell (this is patently not possible with 2.1 GHz spectrum where the amount of spectrum available to each operator could reduce under Option 3). It would therefore require a 5MHz pair from a different frequency band. Implementing this would at the very least involve equipping the base station with a new set of antennas in addition to any other equipment required (it would also need handsets capable of supporting such operation). Therefore, the cost of this upgrade represents the minimum additional cost that an operator will have to account for, which is a substantial proportion of the total CAPEX for a base station.

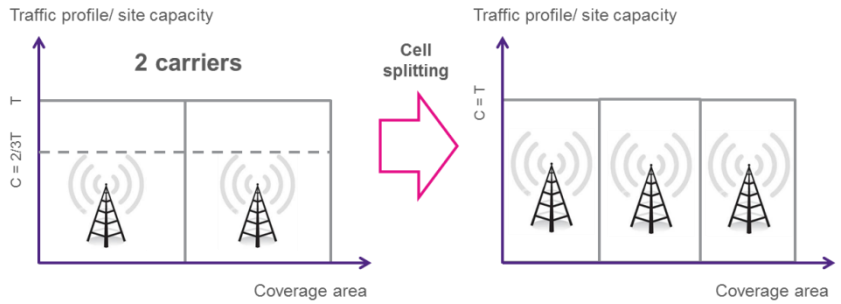
Out of all the bands allocated for mobile use, the only other band that is widely identified as suitable for 3G is 900MHz but there is a shortage of such bandwidth to support the 5 MHz channels required for 3G and it is already heavily used by mobile operators.

A.2 Cell-splitting

Another way of increasing network capacity is to reduce the coverage area of each base station and install new base stations to fill the gaps. This raises the base station count and is known as cell-splitting. In the case where a fully-loaded network using three 2 X 5MHz carriers is deprived of one 5 MHz pair there is a reduction of base station capacity to two-thirds its previous level. This means that fewer users can be accommodated and/or less traffic per user.

An example of cell splitting is shown in Figure A-1 where three cells with a reduced number of carriers are required to maintain traffic capacity in an area where previously two cells were sufficient.

Figure A-1: Capacity enhancement through cell splitting



Source: Plum

Given no change in spectrum bandwidth deployed on each base station, increasing the number of base stations in this way amounts to enlarging the total capacity of the network. However, there has already been a considerable amount of cell splitting implemented in Hong Kong, so the opportunity for use of this method as a means of increasing network capacity will deliver diminishing returns. Further, for Option 3 operators will face a significant additional CAPEX, equivalent to at least one-third of their

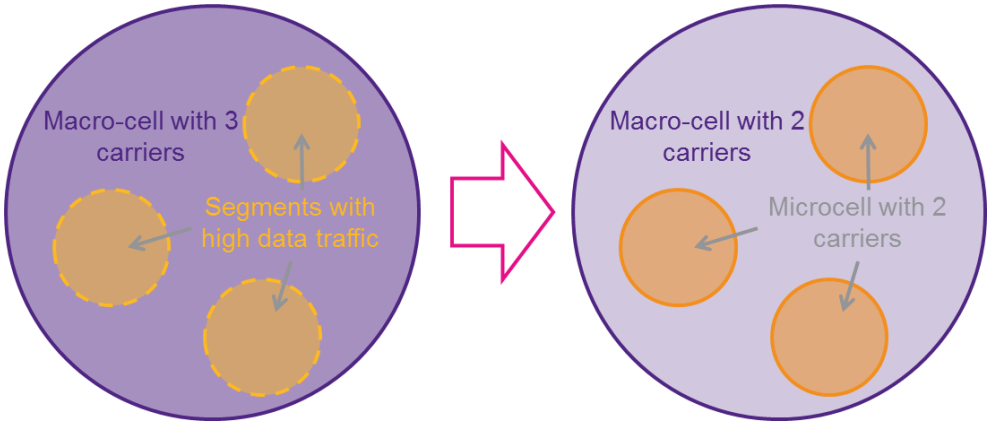
total CAPEX on existing RAN equipment. OPEX will also increase in line with the number of sites. These costs are not efficiency enhancing.

At a practical level mobile network planning in Hong Kong is already complex as the distance between cells in many places is less than a few hundred metres. Reducing the distance between cell sites even further creates problems for cell power control and the search mechanism in handsets. In Hong Kong an additional dimension to consider when splitting cells is that the traffic density has both a horizontal and a vertical dimension in some parts of the territory (e.g. tall buildings and urban canyons).

A.3 Deploying a micro-cell layer

Implementing a hierarchical macrocell-microcell structure could be used to increase network capacity. Under this scheme, areas with higher data traffic can be overlaid with a layer of base stations with lower coverage – these are called microcells. This is a more targeted solution than splitting cells, since the additional capacity provided by the microcell is only available in parts of the coverage area of the macrocell, as shown in Figure A-2. The purple area represents the existing coverage area of the macrocell, and the orange discs on the right hand side of the figure are coverage areas of microcells. This solution is already used by mobile operators in Hong Kong to provide coverage in areas of high traffic density such as shopping malls.

Figure A-2: Hierarchical network scheme with macro and micro cells



Source: Plum

Even though deploying a micro-cell layer could help operators solve the problem of capacity shortfall it is unclear how much further deployment is possible in Hong Kong with its high subscriber and traffic density and the already small distance between cells. The network will have to be re-planned to ensure that interference is kept at an acceptable level to avoid compromising quality of service. Also, the CAPEX required for new microcells may not be much lower than the cost of macro-cells.

Appendix B: International experience in setting renewal fees

In this section we report on approaches used in Australia, New Zealand and the UK to set SUFs for spectrum licences held by mobile operators that were fully renewed on expiry.

In summary the approaches used to set fees on licence renewal were as follows:

- Australia: Modelling of cost reduction and full enterprise value and auction and traded values from Australia and elsewhere.
- New Zealand: Modelling of cost reduction value
- UK: Historically used modelling of cost reduction value but is moving to an approach based on UK and international auction data.

B.1.1 Australia – 850MHz, 1800MHz and 2100MHz

The Australian government decided to reissue the expiring 15-year licences for the various frequency bands, including 850 MHz, 1800 MHz and 2100 MHz, to incumbent operators (Telstra, Optus, Vodafone).[42] The renewal fees were intended to reflect the opportunity costs of the spectrum and to promote efficient use.

The approach used to set the fees was described in a published Plum report[43] and involved:

- A review of international evidence on the value of spectrum licences in the same or similar frequency bands as revealed in auctions and licence renewal processes elsewhere.
- Modelling of values based on the projected revenues and costs of a hypothetical operator. To provide bounds on the value of the spectrum licences the following two measures were modelled:
  - Cost reduction: This is the value arising from the use of an incremental block of spectrum to reduce infrastructure costs. The cost reduction value is calculated by modelling infrastructure costs with and without additional spectrum. In congested areas additional spectrum allows more capacity to be deployed per site (and therefore fewer sites are required). The coverage and in-building penetration advantages of lower frequency bands were values based on differences in the number of base stations needed to provide coverage. It was assumed that the minimum block size for efficient deployment of 3G services is 2x5 MHz while that for LTE services is 2x10 MHz.
  - Full enterprise value: This is the net present value (NPV) of total business cashflows (i.e. revenues less costs) that a mobile operator earns from all of its spectrum holding. This sets an upper bound on what might be charged on licence reissue. A price higher than this level would mean that the operator modelled would go out of business.

The values estimated and the prices offered by the government were as shown in Table B-1. The offer prices were accepted by the operators.

[42] http://www.dbcde.gov.au/radio/radiofrequency_spectrum/spectrumlicences

[43] Synopsis of 15-year spectrum licence valuation methodology, Plum Consulting

Table B-1: Summary of spectrum values in $AUS/MHz/pop (all referenced to value in 2013)

Band	Cost reduction value estimate	Full enterprise value estimate	International benchmark values	Government offer price[44]
800MHz	0.97	3.16	0.5-1.2	1.23
1800MHz	0.15	0.47	Up to 0.23	0.23
2100MHz	0.41	1.01	Not reported publicly	0.625

Sources: Plum Consulting 2011, Synopsis of 15-year spectrum licence valuation methodology, Plum Consulting; Spectrum licence reassignment in Hong Kong - the case of the 1.9-2.1GHz band*; Spectrum licence reassignment in Hong Kong - the case of the* 1.9-2.1GHz band

B.1.2 New Zealand – 850MHz and 900MHz

In 2003, the New Zealand government adopted a policy of reallocation upon expiry to existing right holders, although each case is subject to a case-by-case review.[45] In 2007 renewal offers for 850 and 900 MHz spectrum were made to incumbents Telecom NZ and Vodafone on condition that they each complete a secondary market sale of at least 2x5 MHz to a new entrant (Two Degrees). Two Degrees subsequently renewed the 900 MHz spectrum gained from that sale in 2011. All 850 and 900 MHz licences now expire in 2031.

A consultancy study examined options for estimating market value including 1) benchmarking, 2) earnings and 3) avoided costs or deprival value.[46] Benchmarking was rejected on the grounds that there were few, if any, like for like comparators. Earnings based approaches suffer from the uncertainties about future revenue growth and service/technology change and so the consultants recommended an approach based on deprival value.

The deprival value approach involves valuing spectrum as the difference in network roll-out and operating costs arising from deprival of a given quantity of spectrum for the life of a cellular licence for a generic operator.[47] This is similar to the least cost alternative approach adopted by OFTA for other services. A key advantage of this approach is that the information requirements are not unduly onerous. It requires assumptions concerning:

- Traffic forecasts.
- The technology deployed in future.
- Network configuration with/without the marginal spectrum.
- Network capital and operators costs with/without the marginal spectrum.

[44] Radiocommunications (Spectrum Access Charges) Direction 2012, Direction to the ACMA under sub-section 294 -2 of the Radiocommunications Act 1992.

[45] http://www.rsm.govt.nz/cms/policy-and-planning/projects/recently-completed-work/cellular-rights

[46] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development, http://www.med.govt.nz/templates/MultipageDocumentTOC____20766.aspx;

[47] Renewal of management Rights for cellular Services (800/900 MHz), Network Strategies, Ministry of Economic Development, October 2007 http://www.med.govt.nz/templates/MultipageDocumentTOC____32548.aspx

Values were calculated using the deprival value approach and an analysis of international benchmarks. An offer price of $NZ3.8m/2x1MHz was announced.[48] Incumbent cellular operators accepted this price and other conditions attached to the new licences.[49]

B.1.3 UK – 900/1800MHz fees

The spectrum licences for access to the 900MHz and 1800MHz bands are perpetual. Annual licence fees currently paid by operators were set based on an LCA approach in the late 1990s (with a 50% discount to the estimated values) and have not been reset since then.

The UK Government's Direction to Ofcom made in December 2010[50] required Ofcom to revise the annual licence fees paid for 900 MHz and 1800 MHz to reflect full market value having particular regard to the sums bid for licences in the 800 MHz and 2.6 GHz auction. This situation has some similarities to Option 3 for the 2.1 GHz band under which an SUF is to be set so that it reflects full market value, an auction price will inform the level of the SUF and the operators that pay the SUF may also bid in the auction.

The approach that Ofcom may use to set annual licence fees has been discussed in two recent Ofcom consultation documents[51]. In the first consultation Ofcom made it clear that the Direction required setting fees at "full market value" and this meant the approach taken would be different from the approach it uses to set SUFs in other circumstances. Specifically in its strategic review of spectrum pricing Ofcom recognises that there is likely to be uncertainty in the valuations and so proposed[52]

> *Where there is uncertainty in our estimate of opportunity cost, for example arising from uncertainty in the likelihood of demand for feasible alternative uses appearing, we will consider the risks from setting fees too high, or too low, in light of the specific circumstances*.

Ofcom reviewed possible sources of information for setting annual licence fees including market benchmarks and technical and cost modelling (comparable to the LCA approach) to determine fees. It concluded that market information was more reliable than modelled values and that the amounts bid and licence fees paid in the auction were likely to provide the most reliable basis for estimating the full market value of 900MHz and 1800MHz spectrum[53]. They went on to propose that an estimate of the full market value of 900MHz spectrum should be based on an average of 800MHz prices and that the full market value of 1800MHz spectrum should be based on an average of the 800MHz and 2.6 GHz prices per lot.

Operators argued that a mechanistic link between auction prices and the fees for 900MHz and 1800MHz spectrum licences would affect bidding behaviour in the auction. Ofcom's further analysis (given in Ofcom's second consultation) showed that there were circumstances in which bidding

[48] http://www.rsm.govt.nz/cms/policy-and-planning/current-projects/radiocommunications/rights-at-expiry/cellular-rights/media-statements/government-makes-offers-for-renewal-of-cellular-spectrum-rights-minister-of-communications-and-information-technology-media-statement-published-27-november-2007

[49] These included a use it or lose conditions expressed in terms of coverage requirements.

[50] The Wireless Telegraphy Act 2006 (Directions to OFCOM) Order 2010 (S.I.2010 No. 3024) which can be found at: http://www.legislation.gov.uk/uksi/2010/3024/contents/made

[51] Consultation on 800MHz and 2.6GHz competition assessment and award proposals, Ofcom, March 2011; Second Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6 GHz spectrum and related issues, Ofcom January 2012

[52] AIP Principle 8, page 4, SRSP: The revised Framework for Spectrum Pricing, Ofcom, December 2010

[53] Para A11.9, Consultation on 800MHz and 2.6GHz competition assessment and award proposals, Ofcom, March 2011

behaviour could be distorted and they so rejected use of a mechanistic linkage between 900MHz and 1800MHz fees and auction results. The provisional approach now proposed by Ofcom is to use three sources of information[54]:

- The bids made and licence fees paid in the combined award of the 800MHz and 2.6GHz bands;
- An approach to estimating full market value from bids in the auction which is termed the Additional Spectrum Methodology. This methodology involves estimating the value of spectrum of Company A's 900MHz spectrum holding by first assuming that the same amount of 800MHz spectrum was (hypothetically) included in the auction. The auction bid data for all bidders other than Company A would then be used to estimate the value of the incremental amount of 800MHz spectrum.
- Amounts paid in auctions in other countries for the same or similar spectrum, which may inform the relative value of different frequencies as well as their market value.

The way in which the three sources of information listed above will be used to inform prices will be the subject of a further consultation to be conducted post the now completed 800MHz and 2.6GHz auction.

[54] Para A13.3, Annex 13, Second Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6 GHz spectrum and related issues, Ofcom January 2012.

Appendix C: Economic impact assessment

To evaluate the best approach between Option 1 and Option 3, OFCA should perform a cost benefit analysis on each of the potential outcomes that may occur under the two options.

A scenario based approach to assessment

Option 1 only has a single outcome since it involves the re-assignment of 2.1 GHz licences to existing licensees consistent with their current spectrum holdings. Since there is only one outcome associated with this option it is logical to make this the counterfactual scenario (i.e. the scenario against which the impact of each of the other scenarios is compared).

With Option 3 outcomes vary according to how much of the auctioned spectrum might be regained by existing 2.1 GHz licensees and the type of operator that gains access to the auctioned spectrum.

- Existing licensees are given right of first refusal over 2x10 MHz of spectrum (not necessarily within their current holdings) and it is possible that all four fail to obtain any spectrum in the auction. Alternatively individual 3G licensees may obtain a further 2x5 MHz or more of spectrum.
- Spectrum may be obtained by the other major operator that does not currently have 2.1 GHz spectrum (2x10 MHz, 2x15 MHz or 2x20 MHz). The auctioned spectrum may also be obtained by one or more market entrants that obtain 2x10 MHz, 2x15 MHz or 2x20 MHz.

This results in 10 outcome scenarios as shown in Table C-1. It should be noted that even though Scenario 1 has identical spectrum holdings to the counterfactual, there are still incremental costs associated with the uncertainty during the period leading up to the auction outcome being known and the costs of implementing by OFCA and for all industry players to participate in the auction.

Table C-1: Outcome scenarios associated with Option 3

Scenario	Number of incumbent operators with 2.1 GHz spectrum			Number of incumbent operators without 2.1 GHz spectrum			Number of market entrants		
	2x10 MHz	2x15 MHz	2x20 MHz	2x10 MHz	2x15 MHz	2x20 MHz	2x10 MHz	2x15 MHz	2x20 MHz
1		4							
2	1	2	1						
3	2	2		1					
4	2	2					1		
5	2		2						
6	3	1			1				
7	3	1						1	
8	4					1			
9	4								1

Scenario	Number of incumbent operators with 2.1 GHz spectrum			Number of incumbent operators without 2.1 GHz spectrum			Number of market entrants		
10	4			1			1		

Note: This table assumes that inefficient or anti-competitive outcomes where an operator gains only 2x5 MHz or 2x25 MHz will be prevented by auction design. It also assumes that each of the existing licensees exercise its right of first refusal.

Only incremental costs and benefits should be included

To perform a proper impact analysis OFCA should quantify the incremental costs and benefits associated with each of the scenarios compared with the counterfactual. In doing this OFCA should take full account of the impacts on each category of operator and their subscribers.

Economic impact = incremental benefits – incremental costs

The incremental costs and benefits may arise from consumers and/or operators (i.e. the total economic impact of an outcome scenario includes the impacts on both consumers and operators). We have outlined the service disruption and network costs associated with Option 3 in this report. All of these should be included in the analysis. We believe that significant net benefits are unlikely under any of the scenarios.

Furthermore, there are some important issues to take account of in a proper economic impact assessment:

- Incremental consumer benefits arise from genuine opportunities to access new services that are not available in the counterfactual scenario. There are two operators in the Hong Kong market already able to offer services based on 2x20 MHz carriers (using 1800 MHz or 2600 MHz spectrum). In time, with carrier aggregation all operators will be able to offer services based on 2x20 MHz carriers. Any subscribers with willingness to pay for high bandwidth data services are able to do so in any of the scenarios including the counterfactual. Therefore there is little incremental benefit associated with the facilitation of 2x20 MHz carriers in the 2.1 GHz band.
- Where subscribers are forced to migrate from 3G licence holders that obtain less spectrum there will be a net incremental cost arising from either:
  - Migration to LTE networks requiring consumers to buy new smartphones earlier than they would otherwise choose to; or
  - Migration to other 3G networks supplemented by additional 3G spectrum obtained in the auction. There will be an incremental cost borne by the 3G operators with additional spectrum obtained in the auction (either existing 3G licensees or new networks implemented by the other major operator or a market entrant)

  Note that where the other major operator or market entrants implement LTE in the 2.1 GHz band this will require migrating 3G consumers to purchase new handsets.

  Where consumers are forced to migrate prior to the end of the contracts, this represents a transfer of value from consumers to operators (i.e. no net change to the overall economic impact). However it would be a disruptive and undesirable impact on consumers.

- If OFCA assumes that existing 3G operators that lose 2x5 MHz will implement advanced new technology to compensate for the lost spectrum then the cost of restoring capacity using such new technology must be included as an incremental cost. Moreover, the costs of implementing the new technology in both network and consumer devices must be included (noting that inclusion of advanced MIMO or superfast WiFi to resolve capacity issues will require consumers to purchase a new handset they would not otherwise need to)[55].

The results of the cost benefit analysis will be a net economic impact for each of the scenarios. In the absence of significant benefits arising from Option 3 in any of the scenarios, there is likely to be only varying degrees of net cost across the scenarios.

Drawing conclusions from the analysis

Where any of the scenarios have a negative economic impact then this constitutes risk of regulatory failure. Any decision to adopt Option 3 should only be taken if there are substantial net economic benefits in the majority of scenarios, and when such benefits are real and quantifiable.

However, if OFCA's assessment attributes benefits to any particular scenario (e.g. a weakly justified competition benefit associated with a new entrant gaining access to the band) then it is crucial that such benefits are assessed alongside the full costs of such an outcome (i.e. costs faced by all four 3G licensees losing spectrum and their customers plus the costs of rollout of a new network by the market entrant). Similarly, if benefits are attributed to an existing 3G licensee gaining access to 2x20 MHz of 3G spectrum then this needs to be offset by the net increase in costs faced by the 3G operators that have their spectrum holdings reduced to 2x10 MHz.

It is only by a rigorous consideration of both costs and benefits under each outcome scenario that the true economic impact of adopting Option 3 can be assessed. An approach that quantifies costs and benefits without assuming exactly the same scenarios for each, will introduce bias when drawing conclusions and risk regulatory failure.

[55] Although many consumers in Hong Kong upgrade handsets regularly, these are likely to be the same population of consumers that can be expected to migrate to handsets capable of LTE under the counterfactual scenario. The consumers affected by 3G capacity loss are those who would choose to retain their current handsets under the counterfactual scenario. In the Cisco traffic forecast discussed in Section 2 of this report, 55% of data traffic is expected to be carried on non-LTE networks in 2017.