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Spectral Economic Efficiency

The Report of the Independent Spectrum Broker published earlier this summer in the UK argues the case for a rebalancing of lower and higher band spectral holdings, re farming of the 900 MHz band and a coupling of the 2.6 GHz and 800 MHz auction process.

The recommendations are re stated in the **Digital Britain Report** published in June and are representative of spectral policy thinking in an increasing number of countries so it is useful to think through some of the shorter and longer term cost implications.

The report recommends a development of existing policies based on the assumption that market forces will result in the matching of the price paid for the spectrum to realisable and reasonable value.

If spectrum is auctioned in a way that maximises auction income then this should ensure that the entities winning the auction are incentivised to maximise the efficiency of their spectral holdings.

The problem with this is that auction theory suggests that a maximal price can be achieved if at least five bidders win through to the final round.

More often than not the end result is that the spectrum is then assigned in five separate allocations.

This results in significant spectral inefficiency which translates into additional spectral cost.

These costs are not fully factored in to bid valuations but only become apparent after the evaporation of post auction euphoria.

Market forces have therefore not been efficient in matching the cost of the spectrum to realisable value.

However **alternative approaches can result in even less efficient allocation.**

India provides an example

A report by Aegis Systems and Plum Consulting prepared for the GSM Association at the end of last year analysed the consequences of a policy in which between nine and 16 operators are assigned spectrum in a specific geographic area, known as a circle.

GSM licensees receive an initial 2 by 4.4.MHz of spectrum and CDMA licensees receive 2 by 2.5 MHz and can then claim additional spectrum on the basis of number of subscribers served.

Overall this has resulted to date in a total allocation of between 2 by 40 and 2 by 70 MHz of 2 G spectrum in most circles which compares with most other countries which have allocated between 2 by 90 and 2 by 110 MHz.

The average allocation per operator is 5.5 MHz which compares with an average of 22 MHz for operators in other countries.

When measured in terms of busy hour traffic per square kilometre per MHz in dense urban areas, Indian operators extract around eight times more capacity than operators in the UK, Hong Kong or Singapore.

This would suggest that encouraging more operators to compete within a market delivers spectral efficiency benefits.

However for a number of technical reasons this is **not** the case.

Why narrow spectrum allocations are not *technically* efficient

Cellular networks have a minimum bandwidth that has to be assigned to control signalling to manage session set up, session clear down and session maintenance including power control and handover.

If the amount of traffic channel bandwidth is restricted, then signalling overheads become more significant both in terms of bandwidth and power. For example in GSM, the first 2.4 MHz must be allocated for signalling. The BCCH is transmitted at full power and needs a re use factor of 12.

At network level, a restricted choice of available traffic channels limits frequency reuse between cells and prevents any potential gain being realised from synthesised frequency hopping which requires at least two by 5 MHz to be effective.

Smaller spectrum allocations also result in significantly lower trunking/multiplexing gain.

Utilisation of a cell with a 15 voice channel capacity can reach 60% before the probability of a blocked call in the busy hour exceeds 2%. Utilisation of a cell with 50 channel capacity can reach 80% for the same grade of service.

In order to achieve additional capacity, Indian operators are forced to rely on site distances of less than one kilometer.

When inter cell distances fall below 1000 meters there is increased interference between cells using the same frequency and network capacity is reduced. Additionally the position of the site becomes increasingly important.

The combined effect of these factors is that an operator with 2 by 6 MHz of spectrum can carry six Erlangs of traffic per MHz per sector whereas an operator with 2 by 12

MHz of spectrum can carry nine erlangs of traffic per MHz per sector.

This suggests that there is a 50% increase in traffic carrying capability for each MHz for the operator with additional spectrum. Vodafone have made a similar calculation which shows that halving the spectrum per operator reduces the traffic handling capacity by 33%.

How much additional cost this involves is dependent on the ratio of cells that are capacity limited or coverage limited.

Assuming approximately 35% of traffic is generated in capacity limited cells then the cost of a two by two by 12 MHz allocation will be 21% less per year than a two by 6 MHz assignment.

Or put the other way round, a more generous assignment would reduce industry costs by at least 21%.

Other mitigation options exist to manage higher levels of inter cell interference such as half rate codecs and single antenna interference cancellation

Half rate or variable rate codecs have an associated loss of quality cost and require a higher Eb/No.

Single antenna interference cancellation is effective in capacity limited conditions but incurs a processing overhead.

The technical case against artificially constrained spectral allocations for 2 G networks therefore appears to be robust and will be even more relevant for 3 G networks which are predicated on wider channel spacing and wider operational bandwidths.

These arguments are therefore not only relevant to the particular case of India but can be more generally made for all markets including countries and regions where re farming of existing 900 or 850 MHz spectrum is presently proposed.

Why narrow spectral allocations are not *economically* efficient
Self evidently technical efficiencies translate directly into additional cost which translates directly into a reduction in spectral economic efficiency.

However the reason for promoting narrow spectral allocations is generally to allow more operators to compete within a geographic area.

If these operators do not share backhaul then additional cost multipliers are introduced.

Each additional operator also introduces marketing and administration cost which has to be amortized over a widely fragmented subscriber base.

These technical and commercial factors together depress spectral economic efficiency.

Optimum Bandwidth Allocations
The optimum bandwidth allocation depends on the technology used and the frequency band.

For example if LTE was to be deployed on the basis of utilizing 20 MHz channel spacing then this would be unlikely to be efficient in a 25 MHz band allocation and would be more ideally suited to bands with an operational bandwidth of 50 or 60MHz or more.

However 50 MHz operational bandwidths at 700 or 800 MHz are ambitious in terms of filter roll off requirements. As operational bandwidth increases as a percentage of the centre frequency, filter roll off becomes increasingly problematic and can result in adjacent channel interference and or unacceptable filter insertion loss.

This is particularly important when there are other users in the band who are either operating at high power, digital TV for example, or have receivers with poor selectivity, digital TV for example or are otherwise vulnerable to interfering signals, two way radio and radio microphones being two examples.

These are basic engineering issues which engineers know and understand. Remarkably the associated engineering costs are often not reflected in allocation policy and even more remarkably are not fully factored into bid valuation.

This may be because of a belief that technology solutions will be found but this will only happen if sufficient R and D resource is available to bring these technology solutions to market.

The R and D cost then has to be amortized over available market volumes over relatively short time scales. In practice these technology solutions take longer than expected and operators are faced with the problem of having expensive spectrum that cannot be economically accessed.

The Problem with the Problem
This suggests that it is not sufficient to allow the market to decide on how spectrum should be allocated and auctioned.

Spectral allocation policy has to be based on **sound engineering principles** which result in optimum or at least near **optimum spectral efficiency.**

Competition policy then has to be developed in such a way that optimum or at least near optimum **spectral *economic* efficiency** can be achieved.

On the basis of present evidence, it is not possible to meet either of the above criteria with more than ten operators; it is not possible to meet either of the above criteria with five operators and probably only possible to meet both criteria with either two or three operators per market.

The counter view is that there is so much additional spectrum being brought to market that there will be more than enough for everyone.

So for example an LTE five band handset covering Bands 1, II, III, V and VIII has a total operational bandwidth of 510 MHz.

An LTE 10 band handset adding in the 2.6 GHz band at one end and the 700/800 MHz DSO bands at the other would have an operational bandwidth of 916 MHz.

The snag here is that not all of this bandwidth is available in all markets.

Additionally there is no present visibility as to how five band or particularly ten band LTE handsets could be produced with acceptable cost and performance.

The result is that many operators have spectral allocations that are far from optimum for present technologies and even less optimum for future technologies.

The problem with this problem is that governmental interference is likely to make the situation worse rather than better.

So for example in the UK, the spectrum broker proposals are designed to level the playing field between the five operators, the genesis for the proposed rebalancing of upper and lower band holdings and re farming of the 900 MHz band.

However these proposals are predicated on the continued existence of the five operator model in the UK which is probably unsustainable.

It would seem more sensible to broker a merger that reduces the operator count to three at which point there could be regulatory encouragement to ensure that each of the three operators has a balanced and economically efficient spectral portfolio that takes account all engineering costs including multiband LTE handset development cost and performance constraints.

A similar approach in other markets would result in significant improvements in spectral economic efficiency which could be translated in to lower tariffs and higher operational margins which are an essential precondition to maintaining adequate levels of R and D and engineering investment.

Government policies have been dominated by the short term returns achievable from a manipulative auction process.

They have been aided and abetted by bid teams who have failed to factor in engineering cost to bid valuations.

The proposed coupling of the 2.6 GHz and 800 MHz auctions may or may not be based on some anticipated benefit in terms of auction income or an assumption that a low band high band offering could in some way extend benefits that are assumed to be realizable from the rebalancing of existing low and high band allocations.

This might be justifiable if there was a robust technical rationale behind the policy. Generally it is assumed that a combination of an 800 MHz and 2.6 GHz allocation will provide an optimum combination of economic low band coverage for rural areas and economic high band capacity in urban areas.

This works to an extent with 900 and 1800 MHz where there is a resonant relationship between the two bands but this does not apply to an 800/2.6 GHz band plan. The technical and economic viability of supporting these two extra bands in future multi band handset and base station platforms is presently unproven.

The result of past policy has been that most countries now have cellular networks that are operating on economically inefficient spectrum. This is imposing unnecessary industrial cost which is resulting in unsustainable cuts in R and D and engineering investment.

Present policy or at least proposed policy seems likely to make this worse rather than better. If incompatible technologies are allowed to be deployed into contiguous spectral allocations, as was the case in India, then more unnecessary cost is introduced.

This suggests there may be merit in developing Technology Economics as a discrete sub set of more general economic theory. The objective would be to achieve a closer coupling between engineering theory and practice and economic theory and practice.

This would have the benefit of making spectral allocation and technology decisions more directly responsive to longer term economic viability.

Bringing these traditionally separate disciplines closer together may be a necessary precondition for recovering the profitability needed for the cellular industry to progress.

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