TRAI consultation paper No.11/2004

SPECTRUM ISSUES FOR MOBILE OPERATORS IN INDIA

REPORT FOR THE ASSOCIATION OF UNIFIED TELECOM SERVICE PROVIDERS OF INDIA (AUSPI)

INDEPEN AND INTERCONNECT

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Introduction

The Telecommunications Regulatory Authority of India (TRAI) is currently reviewing its policies on the amount of spectrum that should be assigned to mobile licensees, the basis for assigning additional spectrum and spectrum pricing options. The Association of Unified Telecom Service Providers of India (AUSPI) asked Indepen and InterConnect to address three broad groups of spectrum management issues in the context of the TRAI's review of spectrum policy, namely spectrum allocation, spectrum pricing and spectrum efficiency.

We address these issues using economic and technical analysis and drawing on international best practice. The analysis is undertaken with reference to the TRAI's statutory functions, in particular those relating to making recommendations on

"Measures to facilitate competition and promote efficiency in the operation of telecommunications services so as to facilitate growth in such services"[1] and

"Efficient management of available spectrum"[2].

In addition, it is assumed that any approach adopted should meet the general regulatory principles of transparency and objectivity and should not impose an undue administrative burden on either the regulator or the mobile licensees.

Spectrum Allocation

We have proposed three possible mechanisms for identifying additional frequencies for CDMA services in India. A summary of these proposals is given in the table below.

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[1] para 9(a)(iv), The Telecom Regulatory Authority of India (Amendment) Ordinance 2000

[2] para 9(a)(vii) op cit

Proposal	Result	Pros	Cons
Superposition of CDMA 1900	2 x 20 MHz (1890-1910 paired with 1970-1990 MHz)	Implementable immediately No impact on 1800 MHz services. Only a small impact on 3G services. 1900 MHz spectrum provides compatibility with international market.	Provides lowest amount of spectrum of all proposed solutions. Possible interference problems with existing DECT/corDECT systems. Small reduction in future 3G spectrum.
Superposition of CDMA 1700	2 x 30 MHz (1750-1780 paired with 1840-1870 MHz)	Implementable immediately (subject to possible re-tuning of existing 1800 MHz networks). Provides almost equal allocations for CDMA and mobile/WLL services. No impact on existing DECT/corDECT services or future 3G services. No need for re-assignment of spectrum.	1700 MHz spectrum only compatible with South Korean services implying higher infrastructure/handset costs. Currently no 800/1700 dual-band handsets, so roaming (either overseas or between Indian networks) is severely restricted.
Alternative band plan	2 x 40 MHz 1850-1880 paired with 1930-1960 MHz plus 1900-1910 paired with 1980-1990 MHz)	Provides almost equal allocations for CDMA and mobile/WLL services but greater than previous option. 1900 MHz spectrum provides compatibility with international market.	Proposed 3G allocation would (at the present time) be India specific.

None of these proposals provides immediate, obviously clear spectrum for CDMA services, however the third option, whilst requiring an India specific 3G allocation, offers the most (technology) equitable solution for GSM and CDMA operators, as well as offering both similar amounts of spectrum overall..

If spectrum is to be reallocated to mobile services then spectrum refarming issues need to be considered. Traditionally relocation of incumbent users has been achieved by giving them notice that they will have to vacate bands or adopt new equipment well in advance of the reallocation date. We have reviewed a number of other approaches that are increasingly being used to accelerate the time taken to reform spectrum, including giving incumbents relatively short notice periods; compensation of incumbents by newcomers; setting up a national spectrum fund to pay incumbents to move quickly; spectrum pricing and spectrum trading. Most of these approaches involve giving incumbents a financial incentive to move.

We conclude there is no single approach to spectrum reforming that will work well in all bands – the technical characteristics of spectrum use and the number and identity of users are all relevant to the choice of approach. We suggest that the TRAI should make appropriate allocations of spectrum to the mobile operators and if the spectrum is already being used then it should be vacated using some form of compensation.

Changes in operators' spectrum allocations over time

In most countries the concept of allocating an initial amount of spectrum to an operator and then increasing it at a later date has not been normal practice. Operators have typically received the full amount of spectrum they are to be allocated in a specific band at the time they are first awarded a mobile licence (though parts of the spectrum may have been unusable until existing users migrated). The common exception to this rule has been where the regulator has wished to open up a new band (such as GSM 1800), or where a long-term programme of re-farming has meant that some part of an existing band which was previously used by other users has been vacated. In these instances the regulator has a number of options

Regulators elsewhere have typically allocated all available spectrum to operators because this

promotes the efficient use of spectrum. Leaving spectrum fallow is clearly not effective use, as it is likely to result in less output and higher mobile prices than otherwise.

allows operators to more economically deploy their networks with consequent benefits for consumers in terms of lower prices

reduces administrative costs for operators and the regulator

removes the regulator from having to make often arbitrary decisions about how much spectrum to release initially.

We therefore conclude that the TRAI should assign adequate spectrum to existing operators if it is satisfied that the market is sufficiently competitive. Any new operators would then enter the market with complete knowledge of the availability of spectrum.

Assignment mechanisms

Historically, in most countries radio frequencies were assigned on a first come, first served basis or were reserved for use by specific, often public sector, users. In recent years, increasing demand for radio spectrum has made it necessary to ration the most sought-after spectrum, including spectrum used by mobile operators. Two principal approaches have been adopted to rationing the spectrum, namely administrative selection, based on either first come first served (FCFS) or comparative selection approaches, and market-based selection, using auctions and trading. In Chapter 4 we consider the application of these approaches in the context of assigning additional spectrum to mobile operators.

Administrative approaches

We conclude that FCFS is not suitable for assigning spectrum as it provides no way of rationing demand. Beauty contests are not suitable because of the absence of any clear criteria for choosing between operators wanting additional spectrum. Since technology decisions have been taken by the operators in India, we suggest that TRAI assigns equal amounts of spectrum to all operators on a non-discriminatory basis i.e. irrespective of the technology chosen by any operator.

The Government currently assigns additional spectrum based on the operator's need for the spectrum which is based on subscriber numbers. **This method of allocation is not used elsewhere in the world.** In principle, the concept of "need" could be made more objective by using technical criteria such as erlangs/MHz or erlangs/MHz/km^2. Such measures have been used to determine the efficiency of the throughput of the network for a given amount of spectrum, but do not indicate spectrum efficiency per se, as the results depend on the coverage area and the amount of spectrum allocated to an operator. Operators allocated a small amount of spectrum will, by default, be forced to install a lot of small cells and hence will have a high capacity for a given amount of spectrum. However, this will have been achieved by increased investment a factor not addressed in technical efficiency measures. Technical efficiency criteria are flawed because they do not promote economic efficiency. Also, as discussed below, any actual measures obtained are unlikely to be sufficiently reliable to be used as a regulatory tool.

Administered incentive pricing may have a role in promoting efficient spectrum use although we note that the incentives for mobile operators are weaker than for other users with fewer constraints on spectrum use and mobile operators have strong financial incentives to maximise the use of their spectrum regardless of whether it is priced or not, (given that greater use is associated with increased profits).

Administered incentive pricing is not sufficient as a mechanism to ration spectrum between competing operators for the simple reason that the regulator will not be able to set the "right" price to perfectly ration demand.

Market approaches

Auctions could provide an effective means of assigning additional spectrum in circumstances where the number of bidders (be they just incumbents or incumbents and new entrants) is likely to exceed the number of spectrum lots available. However, in the Indian context it can be reasonably said that there is enough competition in mobile markets and no new entrants are expected to come in. Therefore, the demand for additional spectrum will only be from the existing operators. For reasons of non-discrimination and to ensure the continued viability of existing operators it would not be desirable for only some operators to be assigned additional spectrum. **Therefore, equal assignments together with**

administrative pricing, decided by a clearly defined and transparently adopted formula, is preferable to auctions.

Spectrum trading cannot be used to assign additional spectrum to mobile operators as by definition trading takes place between users. Spectrum trading does however have a useful role to play in facilitating mergers and changes in spectrum use. In developing spectrum policy for the longer term we suggest the TRAI should consider the possibility of implementing spectrum trading arrangements.

Spectrum caps as proposed by TRAI appear play a useful role in ensuring that operators compete on a similar basis in respect of their spectrum holdings.

Spectrum Efficiency

There is a wide range of metrics which can be used to measure spectrum efficiency from the highly theoretical to modelling a real-world situation. Many of the more theoretical metrics are useful for comparing the performance of two (or more) competing technologies in certain, highly idealised, circumstances. However, they are less useful in determining the spectral efficiency of a technology on its own, or against any internationally recognised standard. The same technology can appear more or less spectrally efficient than a competing technology depending upon the input assumptions applied.

Modelling a live network is even more prone to provide results which are anything but meaningful. Small changes in the area covered, location and the time of day for which the model is run and assumptions about subscriber numbers and traffic numbers will significantly impact the results. Furthermore, such modelling cannot easily take account of the local topographical and geographical situation, nor can the impact of interference between cells, either on the same network, or from a remote network, be reliably predicted. Network operators use models to help plan their networks and not to determine their performance.

The ability of a network operator to use spectrum efficiently is directly affected by the way in which it is assigned. The smaller the area over which an allocation is made and the smaller the allocation, the less flexibility there is for the network operator to operate in a spectrally efficient manner. This because in bordering areas, and on those frequencies which are at the edge of the allocation, concessions to neighbouring spectrum users need to be made to prevent interference.

Conclusions

Mobile operators in India must be assigned more spectrum so that they cater for demand growth at least cost. All spectrum allocated to mobile services should be assigned as soon as possible as this is consistent with the TRAI's objectives to promote competition and efficient spectrum use.

Spectrum should be assigned on a non-discriminatory, technologically neutral basis. **This means assigning equal (or equivalent) amounts of spectrum to different operators and spectrum prices being set on the same basis for all spectrum.** In practice, it is not likely to be possible to assign all operators the same amount of spectrum because some frequency bands can only be used by particular technologies. Nevertheless, it should still be possible to offer operators similar amounts of spectrum. In India there is at present relatively little spectrum allocated to CDMA as opposed to GSM services. We have proposed several ways in which this imbalance could be addressed.

The mechanism used to assign additional spectrum should be transparent and non-discriminatory. If the TRAI wishes to license additional operators then auctions might be considered. If, however, the number of operators is judged to be sufficient then a competitive mechanism is not necessary and all operators should be offered sufficient spectrum so that they all have equal amounts in total. There is no merit in rationing spectrum based on measures of spectrum efficiency, as this is economically inefficient and such measures have little meaning as they depend on the input assumptions and the way spectrum currently used was assigned.

Introduction

Scope of this report

The Telecommunications Regulatory Authority of India (TRAI) is currently reviewing its policies on the amount of spectrum that should be assigned to mobile licensees, the basis for assigning additional spectrum and spectrum pricing options. Decisions on these issues could have an important effect on the competitive development of the mobile sector and the likelihood of forecast rapid growth in demand for mobile services in India being realised.

The Association of Unified Telecom Service Providers of India (AUSPI) has asked Indepen and Interconnect to address three broad groups of spectrum management issues in the context of the TRAI's review of spectrum policy, namely

spectrum allocation

spectrum pricing

spectrum efficiency.

Under spectrum allocation, we have reviewed international practice for allocating spectrum to mobile licensees. The following questions are addressed

Which frequency bands have been allocated to CDMA mobile operators?

On what basis was the spectrum allocated?

What is the minimum size of allocations?

What new bands could be earmarked for CDMA in India?

Which bands are most efficient for a combination of voice, data and video?

How should spectrum be reallocated from existing users (e.g. non-commercial users) to mobile operators, including mechanisms to encourage incumbents to move to less congested bands?

Issues of spectrum pricing and efficiency relate directly to the development of options for a new assignment policy for additional mobile spectrum. The questions we address here include

What are the options for mechanisms for assigning spectrum to licensees? What is the impact of the options on competition, cost of service and efficiency?

How much spectrum should be assigned to different licensees?

What should be the basis for any difference in amounts assigned to different licensees?

Should users pay for the spectrum they are assigned and if so how?

Should there be a cap on each operator's spectrum holdings?

How should spectrum be treated in the case of mergers?

What spectrum efficiency measures might be used in deciding how much spectrum to assign to different licensees?

These questions are addressed using economic and technical analysis and drawing on international best practice. The analysis is undertaken with reference to the TRAI's statutory functions, in particular those relating to making recommendations on

"Measures to facilitate competition and promote efficiency in the operation of telecommunications services so as to facilitate growth in such services"[3] and

"Efficient management of available spectrum"[4].

In addition, we assume that any approach adopted should meet the general regulatory principles of transparency and objectivity and should not impose an undue administrative burden on either the regulator or the mobile licensees.

Context

In India full mobility licences using GSM technology were initially auctioned in the metros, and later in all states. Wireless Local Loop (WLL) licences using CDMA technology were assigned on a first come, first served basis and were later modified to become WLL(M) licences offering subscribers limited mobility within a local area. These WLL(M) licences have been converted to full mobility status under the unified licensing proposals, .[5] There is now competition between up to six mobile operators in many parts of India.

The Government has adopted an incremental approach to spectrum assignment with the amount of spectrum assigned to licensees increasing as service demand increases. GSM licensees initially received 2x4.4 MHz spectrum but have been allotted additional spectrum, up to a maximum of 2x10MHz (going upto 12.5 +12.5 Mhz in some metro areas), depending on the number of subscribers in each service area. CDMA licensees initially receive 2x2.5MHz of spectrum and may receive additional allotments up to a maximum of 2x5MHz again depending on subscriber numbers and roll out obligations. We understand that the difference in allotments to GSM and CDMA operators is because CDMA technology is regarded as more efficient than GSM. The regulator has proposed a cap of 2x15 MHz/operator in Metros and Category A Circles and 2x12.4 MHz/operator in Category B and C Circles in respect of spectrum for the GSM operators.

Spectrum used by mobile operators is not licensed separately from the telecoms service using the spectrum. However, mobile operators pay a separate charge as a licence fee for the use of spectrum in the form revenue share. The charge structure is as follows[6]

2% of adjusted gross revenues (AGR) for holdings of up to 2x 4.4 MHz

3% of AGR for holdings up to 2x 6.2 MHz.

4% of AGR for holdings of 2x 10 MHz.

5 % of AGR for holdings of more than 2x10 MHz.

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[3] para 9(a)(iv), The Telecom Regulatory Authority of India (Amendment) Ordinance 2000

[4] para 9(a)(vii) op cit

[6] See www.dotindia.com/cmts/cmtsindex.htm

The Government's approach to assigning and pricing spectrum used by mobile operators differs from that used by telecom regulators in Europe, the Americas and many countries in Asia. Other regulators tend to assign larger blocks of spectrum initially and increasingly use economic criteria (e.g. auctions) to assign licences. Current best practice is demonstrated in the approaches used to assign spectrum for 3G services. Both beauty contests and auctions have been used to assign the spectrum and in all cases all the available spectrum has been allocated and a technology neutral approach to assignment adopted (see Table 1).

Table 1: International Examples of Frequencies Allocated to 3G Licensees

Country	Licence Assignment	Frequencies per licence
Austria	Auction	12 lots of 2x5 MHz, and 5 lots of 1x5 MHz.
Belgium	Auction	2 x 15MHz + 5MHz equally.
Denmark	auction (sealed bid)	2x15MHz + 5MHz equally
Finland	comparative tender	2 x 15MHz + 5MHz equally – leaves 15 MHz.
France	comparative tender	2002: 2x40MHz ; 1.1.2004: 2x60MHz + 20MHz equally.
Germany	Auction	5 licences with 2x10MHz + 5MHz ;1 licence with 2x10MHz
Greece	Auction	3 licences with spectrum sizes varying from 2x20 MHz to 2x10 MHz.
Ireland	comparative tender	2x15MHz + 5 MHz for all licences
Italy	Auction(preceded by beauty contest phase)	2 licences with 2 x 15MHz + 5MHz and 3 licences with 2x10MHz + 5MHz
Netherlands	Auction	2 licences:2x15MHz +5MHz; 3 licences : 2x10MHz + 5MHz
Portugal	Comparative tender	2 x15MHz + 5MHz for all licences.
Spain	comparative tender	2 x 15MHz + 5MHz for all licences
Sweden	comparative tender	2 x 15MHz + 5MHz for all licences; new entrants (2 max.) receive GSM spectrum (900 & 1800MHz)
Switzerland	Auction	2x15 MHz for all licences
United Kingdom	Auction	A::2x15MHz+5MHz.B:2x15MHz C,D,E: 2x10MHz + 5MHz
Hong Kong	Hybrid comparative tender and auction	All 2x14.8 MHz +5 MHz
Japan	Comparative tender	2x 15 MHz from 2x 20MHz for each licence in each area
New Zealand	Auction	Either 2x10 MHz +5MHz or 2X15 MHz +5 MHz
Singapore	Auction	One of 2x15 MHz + 5MHz; Rest 2x14.8 MHz +5 MHz
Taiwan	Auction	Three 2x15 MHz+ 5 MHz One 2x 20MHz One 2X10 MHz + 5MHz

Sources: McKinsey (2002), *Comparative Assessment of the Licensing regimes for 3G Mobile Communications in the European Union and their Impact on the Mobile Communications Sector*, Report for the European Commission, 25 June

2002, Xavier (2001), *Licensing of Third generation (3G) Mobile, Paper for the ITU Workshop on Licensing 3G Mobile*,; European Commission website

Report Structure

The remainder of this report is structured as follows

Chapter 2 addresses issues concerning the allocation of the spectrum to mobile services and mechanism for refarming spectrum in order to change allocations;

Chapter 3 discusses examines the question of whether or not operators should be allocated a single block of spectrum or whether allocations should be gradually increased over time in response to market developments;

Chapter 4 discusses different mechanisms for assigning additional spectrum to mobile operators and the role of spectrum caps

Chapter 5 addresses spectrum efficiency issues.

Spectrum Allocation

Introduction

Indian CDMA operators have currently been assigned spectrum in the 800 MHz band. GSM operators have been assigned spectrum both at 900 MHz and 1800 MHz. Expansion of CDMA services is foreseen at 1900 MHz, however there is a direct conflict between assigning spectrum at 1900 MHz for CDMA and assigning spectrum at 1800 MHz for GSM and at 2100 MHz for 3G (UMTS). This chapter describes the frequency bands for CDMA and their pros and cons, potential new bands for CDMA in India, minimum frequency assignments and mechanisms for refarming spectrum.

Frequency bands for CDMA

Mobile services (in addition to WLL services) based on CDMA technology operate in four different frequency bands around the world. The following table details these bands, and gives a (non-exhaustive) list of countries in which these allocations are used.

Band	Allocation (uplink)	Allocation (downlink)	Countries	Notes
CDMA 450	452.5 - 457.5 MHz	462.5 - 467.5 MHz	Romania, Russia	Other bands around 450 MHz are being considered
CDMA 800	824 - 849 MHz	869 - 894 MHz	Australia, Brazil, Canada, China, India, Indonesia, South Korea, Thailand, USA	Overlaps partially with GSM 900 allocation in India.
CDMA 1700	1750 - 1780 MHz	1840 - 1870 MHz	South Korea only	Completely overlaps with GSM 1800 allocation
CDMA 1900	1850 - 1910 MHz	1930 - 1990 MHz	Argentina, Canada, Indonesia, USA	Overlaps with GSM 1800 allocation

CDMA 800 and 1900 are the most common bands in use and hence have the widest range (and lowest price) of equipment and handsets available. In Korea, equipment operating in the CDMA 1700 band is available though this is specific to the Korean market. We understand that dual-band handsets for CDMA 800 and CDMA 1700 are not yet available, nor is there any commercial pressure for such handsets to be developed. Those Korean CDMA operators who use CDMA 1700 frequencies are different from those who use CDMA 800 and thus there is no imperative for dual-band handsets to be manufactured.

The 450 MHz band is a throw-back from the use of these frequencies in certain European nations (typically the Scandinavian countries and central European countries) for the NMT analogue telephony standard introduced in the early 1980s. As these networks have closed, the operators have sought other ways to exploit their spectrum allocations. That being said, various other countries (including China, Tunisia, Malaysia, Italy, Turkey, Indonesia and Thailand)[7] are considering its introduction, albeit with slightly different frequency allocations to that indicated above. The main advantage of the use of frequencies around 450 MHz is the large coverage area that can be achieved with a single cell-site, though this together with the very limited amount of spectrum available is counter-productive in areas of high traffic density.

With the exception of the 450 MHz band, the allocations used for CDMA conflict to a lesser or greater degree with the bands in use for GSM. In the case of CDMA 1700 as used in Korea, this overlaps completely with the GSM 1800 allocation such that the two systems can not co-exist. Further, the different duplex spacing (90 as opposed to 95 MHz) means that there would be unused guard bands between any co-existing CDMA 1700 and GSM 1800 allocation. The CDMA 800 band overlaps with 14 MHz of GSM spectrum (more if suitable guard-bands are implemented) such that decisions as to which technology is to use the spectrum, and this how it is to be allocated, need to be taken by a regulator (or some industry consensus met) as the spectrum needs to be packaged accordingly. The CDMA 1900 spectrum overlaps by 30 MHz with GSM 1800 spectrum and by 45 MHz with the most popular 3G (UMTS) band, and thus similar arrangements need to be organised.

At the current stage of development of the Indian mobile telecommunications market it would be prudent to follow those international trends which allow for the lowest-cost entry point for subscribers. Thus whilst, in the longer term, the size of the Indian domestic market means that it could take unilateral decisions on spectrum usage for mobile services, or follow more unusual frequency plans, for today, **keeping to the most common international allocations (which for CDMA implies the use of 800 and 1900 MHz) would be the most economical way forward.**

There are strong economic reasons for implementing CDMA services in the spectrum in which it is currently known to operate, the mass production of equipment for existing frequencies significantly lowers the cost of service provision. However an increasing number of 'non-standard' bands are being opened up for CDMA (or other technology) services. In the USA for example, spectrum is being auctioned in frequencies around 700 MHz for flexible fixed, mobile and broadcast uses, though this spectrum is currently occupied by

[7] http://www.itu.int/ITU-D/imt-2000/documents/Slovenia/Presentations/Day%203/3.3.1_Chandler.pdf

broadcasting and will take some time to vacate.[8] It is to be expected that once this spectrum is licensed, the necessary modifications to network infrastructure and handset design will lead to a of the production of equipment in this frequency range, however the use of such non-standard bands is financially untenable.

CDMA 1x is one of the accepted standards for IMT2000 and thus can operate in the spectrum allocated to this service. However the situation is further confused because the 1900 MHz bands often used for CDMA conflict with the IMT2000 assignment. This is particularly acute in the US, and the FCC and NTIA are under pressure to identify alternatives. At the last World Radio Conference, the ITU deemed 2 bands, and within those bands, 7 separate frequency arrangements for 3G services (see the table below). These combinations take account of the varied world-wide situation such that at least one solution can be (or could be with the necessary action to clear existing users) deployed.

Band	Uplink (MHz)		Downlink (MHz)		Unpaired (MHz)	
IMT 2000 A1	824	849	869	894		
IMT 2000 A2	880	915	925	960		
IMT 2000 B1	1920	1980	2110	2170	1880	1920
					2010	2025
IMT 2000 B2	1710	1785	1805	1880		
IMT 2000 B3	1850	1910	1930	1990	1910	1930
IMT 2000 B4	1920	1980	2110	2170	1880	1920
	1710	1785	1805	1880	2010	2025
IMT 2000 B5	1850	1910	1930	1990	1910	1930
	1710	[1750]	1805	[1845]		
	[1750]	[1800]	2110	[2160]		
IMT 2000 B6	1850	1910	1930	1990	1910	1930
	1710	1770	2110	2170		

The A1 band is clearly the existing CDMA800 allocation, and the A2 the existing GSM allocation. The B bands are a combination of the existing GSM 1800 (CDMA 1700), CDMA 1900 and some new frequencies, typically around 2110-2170 MHz.

Current Indian Spectrum Allocation

According to the 2002 Indian National Frequency Allocation Table[9], the following bands are currently assigned for the purposes of cellular or WLL in India:

[8] Spectrum in the lower 700 MHz band has been auctioned. New licensees must protect incumbent broadcasters from harmful interference. Incumbents will be required to vacate the band by the end of 2006 if less than 15% of households do not have access to digital TV. The upper 700 MHz will be auctioned in future.

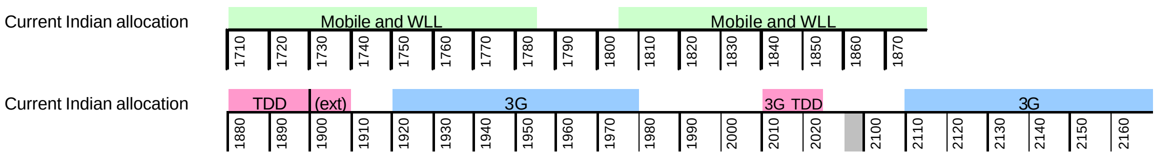
[9] Source: http://www.dotindia.com/wpcc/NFAP/nfap2002cover.htm

Frequency (MHz)			Use	Notes
824	-	844	WLL	Footnote IND41
869	-	889	WLL	Footnote IND41
890	-	902.5	Cellular	Footnote IND43
902.5	-	915	Cellular (extension)	Footnote IND44
935	-	947.5	Cellular	Footnote IND43
947.5	-	960	Cellular (extension)	Footnote IND44
1710	-	1785	Cellular/WLL	Footnote IND48
1805	-	1880	Cellular/WLL	Footnote IND48
1880	-	1900	TDD WLL	Footnote IND49
1900	-	1910	TDD WLL (extension)	Footnote IND50
1920	-	1980	3G (paired)	Footnote IND51
2010	-	2025	3G (unpaired)	Footnote IND51
2110	-	2170	3G (paired)	Footnote IND51

In the 800/900 MHz bands, there is (2 times) 20 MHz available to WLL systems operating at 800 MHz and (2 times) 12.5 MHz available to cellular systems operating at 900 MHz, with a possible additional 12.5 MHz depending on the availability of a particular set of frequencies and the circumstances of each operator.

There is little scope for further modification of these bands as they already occupy all of the possible spectrum which might be made available for mobile or WLL services in this band.

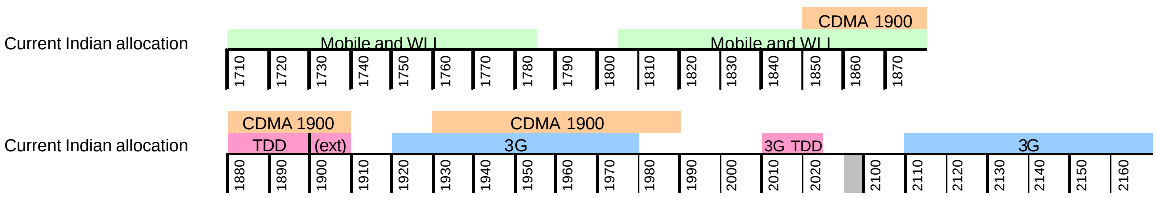
The situation in the higher frequency range is illustrated in the following diagram:



In the 1800 MHz band, (2 times) 75 MHz is available to mobile and WLL services, with an additional 20 MHz for TDD services available between 1800-1900 MHz. A further 10 MHz for the proprietary Indian TDD WLL standard corDECT is available between 1900 and 1910 MHz.

Overlay of CDMA 1900

If we now overlay the CDMA 1900 allocation onto the existing plan, it is clear that, *prima facie*, there is no spectrum available in which CDMA 1900 services can operate without impacting existing allocations.



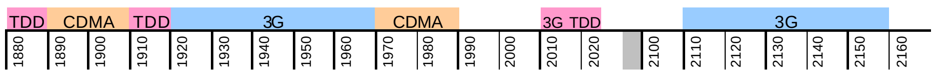
The lower CDMA 1900 band, in which the mobile handsets transmit (and the base stations receive) is already allocated to both mobile/WLL services and to TDD WLL services. The upper CDMA 1900 band, with the exception of 10 MHz between 1980 and 1990 MHz overlaps completely with the proposed Indian 3G allocation. To make matters worse, the mobile/WLL allocation with which the lower CDMA 1900 allocation overlaps is the band in which, for the mobile/WLL services, the base station transmits, and the band for CDMA 1900 in which the base stations receive, thus it is necessary to leave a guard band between the two services in order to stop the strong transmit signals from the mobile/WLL base stations from overloading the CDMA 1900 base stations. The same situation applies between the upper CDMA 1900 band and the lower 3G band.

The 3G band proposed in India is that used in European countries (and Japan) which have already adopted W-CDMA/UMTS as their 3G technology and offers an upgrade path to those mobile operators currently operating GSM networks. Equipment for this frequency band is already available. CDMA technology has its own upgrade path to 3G and does not require additional spectrum in order to make the transition. Whilst there are no 3G services currently in operation in India, the incursion of CDMA services into the 3G band may be seen to preclude the upgrade path for existing GSM operators, however if alternative frequencies are used for 3G in India this would not be the case.

There is potential for implementing an allocation to CDMA 1900 services in India. The services operating in the TDD band between 1880 and 1910 MHz are based on the European standard 'DECT' (Digital Enhanced Cordless Telecommunications) which is a system that seeks a clear channel before establishing a connection. Thus any interference (either from an outside source or other DECT equipment) in the band in which it operates is circumvented. The only difficulty arises when the band is so congested that there are no clear frequencies, however there is little evidence, in Europe or elsewhere, of significant congestion occurring. It would therefore be possible to overlay CDMA 1900 services onto the existing TDD band allowing the DECT technology to avoid the interference caused by the CDMA 1900 transmission. In addition, the ITU 3G allocation which India has chosen to follow includes a TDD allocation between 1880 and 1920 MHz, which, if India adopted this allocation, would provide an additional 10 MHz of TDD spectrum adjacent to the frequencies currently employed.

One possible scenario for a CDMA 1900 allocation in India would therefore be as shown in the following diagram.

CDMA 1900 included



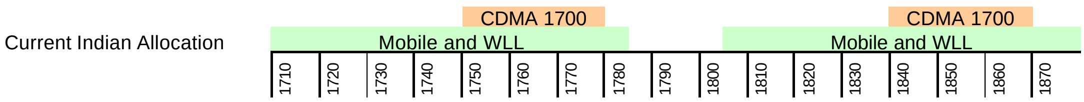
CDMA is allocated (2 times) 20 MHz with 1890-1910 MHz paired with 1970-1990 MHz. TDD loses 20 MHz but gains an additional 10 MHz between 1910 and 1920 MHz. 3G loses (2 times) 10 MHz[10]. No guard band is required between the CDMA and TDD services as the TDD services will adapt to using only those frequencies which are sufficiently clear of CDMA interference. In addition, no modification to existing TDD equipment is required; the TDD and CDMA services can share the band as the TDD equipment will automatically change frequency to avoid receiving interference from the CDMA services (and thereby largely avoiding causing interference to the CDMA services).

Thus it should be possible to allocation (2 times) 20 MHz to CDMA 1900 services in India with minimal disruption to existing services, and only a small impact on future 3G migration opportunities for GSM operators.

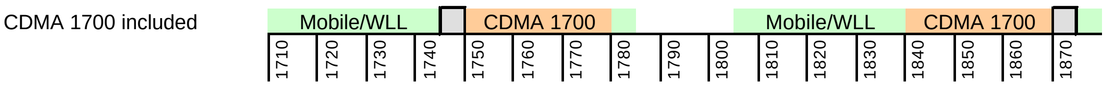
[10] Though there may need to be an additional guard band between the CDMA and 3G services

Overlay of CDMA 1700

Overlaying the CDMA 1700 allocation on to the plan reveals a different outcome.



The CDMA 1700 allocation is encompassed by the existing Indian mobile/WLL allocation, though the duplex spacing (ie the spacing between the transmit and receive frequencies) is slightly different. This difference in duplex spacing means that if spectrum were allocated to CDMA 1700 services, there would need to be a 5 MHz band between them and the existing mobile/WLL services. This is not a guard band (as the mobile and base transmit frequencies are in the same bands and hence interference between base stations is not an issue) but is just caused by the nature of the spacing. The diagram below shows one possible allocation.



In this scenario, CDMA ends up with an allocation of (2 times) 30 MHz, and GSM with an allocation of (2 times) 40 MHz, with 5 MHz gaps (shown shaded) formed in both bands due to the difference in duplex spacing.

The problem with the CDMA 1700 band is that the only other country where it is in use is South Korea and at the moment there are no dual-band CDMA 800/1700 handsets available, and these are not expected to become available in the short to medium term. Infrastructure and handsets will therefore be more expensive than the equivalent equipment at 1900 MHz plus opportunities for roaming onto other networks are reduced.

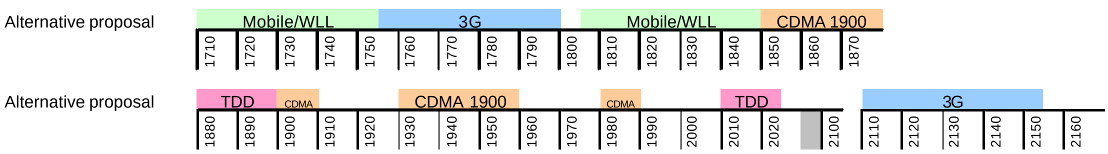
In addition, it is not clear (from the Indian National Frequency Allocation Table) which parts of the 1800 MHz band are already assigned to existing mobile/WLL operators. It may be that it is in the bands that are best occupied by CDMA services (ie those at the lower end of the allocation) that existing services already exist. Thus there would potentially be a significant migration issue for existing operators in this band, depending on whether or not the equipment they have used is frequency agile (most modern equipment is frequency agile, however to reduce costs, older, non-agile equipment, may have been deployed).

This allocation has no impact on existing Indian TDD services, nor on the potential for 3G services in the bands currently assigned in India. Further, as the spectrum used by the CDMA 1700 services is currently assigned for the purposes of ‘mobile/WLL’ which clearly CDMA services are, there is no need for a lengthy re-farming process in order to make the spectrum available.

Alternative band plan

Spectrum allocation to mobile services in India is slightly different to that in many other parts of the world due to historical reasons and, in particular, the fact that the GSM networks started earlier. With this in mind, there is a now need for maintaining spectrum equality,and adopting the technology neutral approach suggested by the Government. A workable band plan needs to be put in place in such a way that both GSM and CDMA technologies can grow equally. As illustrated in section 0, the ITU has proposed a number of alternative frequency allocations for 3G in an attempt to provide potential allocations in countries which already have existing 1700, 1800 or 1900 MHz services. Band B1 is the band which India has currently adopted and is the only band for which 3G equipment is currently manufactured (if one excludes CDMA 1900 services operating in IMT2000 Band B3).

Keeping in mind the above there is an alternative allocation for CDMA in India based around the use of IMT 2000 Band B5 as shown in the diagram below.



This proposal is aimed at establishing a level playing field between the GSM and CDMA operators It is also in line with the Indian Government's policy of technology neutrality – allowing all technologies to grow without impacting each other.

Whilst *prima facia* this proposal is technology neutral inasmuch as it offers similar amount of spectrum for GSM, CDMA and 3G operators, the proposed 3G allocation although complying with IMT-2000 band B5 would be India specific. As the implementation of a 3G service in India is yet a number of years away, the use of an Indian specific allocation may have little effect as such country specific allocations become more commonplace as regulators struggle to find spectrum for 3G.

A less serious, but nonetheless important issue is that no guard band has been left between the lower CDMA 1900 allocation and the upper Mobile/WLL allocation, which would be required due to the previously described incompatibility between the way in which the base station frequencies are allocated.

It might be argued that assigning the 1900 MHz spectrum to CDMA would result in lost revenues for the government as the spectrum might have otherwise been auctioned to 3G operators. This argument ignores the government tax revenues that would flow from the 2G services using the spectrum. More importantly this argument ignores the economic benefits (e.g. GDP contribution) that accrue from the fact that the spectrum is used by a high value application such as mobile and the competitive benefits and lower prices that arise from assigning additional spectrum to CDMA operators.

Conclusions

We have proposed three possible mechanisms for identifying additional frequencies for CDMA services in India. A summary of these proposals is given below.

Proposal	Result	Pros	Cons
Superposition of CDMA 1900	2 x 20 MHz	Implementable immediately No impact on 1800 MHz services. Only a small impact on 3G services. 1900 MHz spectrum provides compatibility with international market.	Provides lowest amount of spectrum of all proposed solutions. Possible interference problems with existing DECT/corDECT systems. Small reduction in future 3G spectrum.
Superposition of CDMA 1700	2 x 30 MHz	Implementable immediately (subject to possible re-tuning of existing 1800 MHz networks). Provides almost equal allocations for CDMA and mobile/WLL services. No impact on existing DECT/corDECT services or future 3G services. No need for re-assignment of spectrum.	1700 MHz spectrum only compatible with South Korean services implying higher infrastructure/handset costs. Currently no 800/1700 dual-band handsets, so roaming (either overseas or between Indian networks) is severely restricted.
Alternative band plan	2 x 40 MHz	Provides almost equal allocations for CDMA and mobile/WLL services but greater than previous option. 1900 MHz spectrum provides compatibility with international market.	Proposed 3G allocation would (at the present time) be India specific.

None of these proposals provides immediate, obvious clear spectrum for CDMA services, however all are workable to a greater or lesser degree. At the current state of development of the Indian mobile market, the third option appears to offer the greatest potential as:.

It provides near equity between GSM and CDMA (and future 3G) operators.

It provides the largest amount of spectrum for GSM and CDMA operators of all the options considered.

It allows networks (GSM and CDMA) to operate in internationally recognised bands, thereby ensuring the availability of handset and infrastructure (as well as the potential for roaming) at reasonable cost;

It is in line with ITU recommendations.

Whether or not the India specific 3G allocation which results as part of this option would cause problems for Indian operators in adopting 3G would depend largely on the timing of its introduction. There are also a number of other countries where GSM 1800 and CDMA 1900 networks co-exist (Pakistan and Nepal for example) and it is possible that these countries may decide to opt for a similar solution to the issues associated with spectrum allocation to that proposed here, increasing the market for such equipment.

Benefits of higher and lower frequency bands

Fundamentally, the questions over whether one particular band of frequencies is of more utility than another comes down to two key issues

the actual frequency employed

interference from other services.

The frequency employed determines the range that is achievable from each cell; given that all other factors are the same (such as transmitter power and antenna height) the lower the frequency, the greater the coverage achieved. In a free-space environment (i.e. one where the transmitted signal is not affected by any other factors than the attenuation caused by distance) a doubling of frequency halves the range of transmission meaning that the area covered is only one quarter the size. Thus in such a simplistic situation, a GSM 1800 cell would cover only one quarter the area of a GSM 900 cell.

However, in the real world, coverage is affected by a number of other factors, in particular attenuation of the signal caused by passing through objects and structures (hills, buildings, vegetation etc), as well as interference caused by other cells operating on the same frequency. Thus in rural environments where there are few physical obstructions, lower frequencies do provide better coverage than higher frequencies, however in dense urban areas, the limitation in coverage is much more likely to be caused by other factors.

One other factor which can impact the coverage of a cell, though not frequency related, is the need to provide capacity in densely populated areas. While a cell might be capable of covering a reasonably wide area, the population of subscribers within this area may be too great for the cell to handle the traffic, in which case additional, smaller cells will be overlaid on top of the coverage of the larger cell to provide capacity where necessary. The coverage of the smaller cells is not limited by topography or obstructions, but by the need to ensure a sufficiently small coverage area so as to be able to deal with the traffic in hot-spots. Obviously if more spectrum were available, this could be employed as an alternative to cell splitting, however there may still come a point where smaller cells would be required.

Another small difference between the use of higher versus lower frequencies is that of the speed of mobility. Taking for example the GSM standard, GSM 900 is specified to function on objects moving at speeds of up to 250 km/h, whereas GSM 1800 is only specified to function at speeds of up to 125 km/h. In the majority of cases this has no material impact on the service, the possible exception being the use of mobiles on high speed trains. This difference is caused partially by the need for the mobile to hand-over from one cell to another. Higher frequency cells are typically smaller and so there will be more hand-overs required for the same call than for lower frequencies. The main difference however is simply Doppler shift which changes the apparent frequency of a transmission dependant upon the speed with which two objects are moving relative to each other (the police siren effect).

Thus from a technical perspective, lower frequencies are typically better for covering large, mostly rural areas, whereas higher frequencies have some advantages when trying to provide capacity in densely populated areas.

The issue of interference from other services can also impact the utility of a specific band of frequencies. If, for example, the edge of the band concerned was adjacent to a series of high-powered transmitters (such as television broadcasting), it is likely that any transmissions in the border between the two services would be swamped if receivers were situated near the high power transmitters. As mobile handsets could be situated virtually anywhere, it is these which are the most susceptible to such inter-service interference. Base stations can still suffer, however there is the potential for them to avoid the high power transmitter either geographically by being situated a greater distance from it, or in frequency terms by avoiding the frequencies adjacent to the high power transmitter. This latter concept of avoiding neighbouring frequencies is termed a 'guard band' as it is a band of frequencies that can not be used in some areas to guard against the problems identified.

The potential for such interference occurs in India in a number of places

the lower end of the CDMA 800 band is adjacent to the UHF television band

the upper end of the CDMA 800 band is adjacent (overlaps) with the lower end of the GSM 900 band. This will cause problems for both types of network and in other countries where both technologies are used, it is normal for there to be a (typically around 2 MHz) guard-band between the two

frequencies in and around the CDMA/GSM 1700/1800/1900 bands are traditionally used for fixed links. A mobile handset in close proximity to a link operating in this band could cause and suffer mutual interference.

Insofar as the use of any particular band for a given type of service (such as voice or data) is concerned, there is nothing to choose between them, the characteristics of the bands having no discernable effect on the ability of the frequencies to provide any given service (the only minor exception being the issue of speed of mobility).

Minimum Spectrum Assignments

Providing an answer to the question of what the minimum spectrum allocation for a given technology should be is not straightforward. In theory, of course, the minimum spectrum required is that which can offer just one voice channel over the appropriate area. For GSM this means assuming a frequency re-use pattern, to ensure that interference is not caused between adjacent cells. The typical re-use pattern is 7 (a tessellated hexagon) and thus 7 channels each of 200 kHz, giving a total of (2 times) 1.5 MHz (including guard bands) is the absolute minimum in which a service could feasibly be operated. For CDMA the channel bandwidth is 1.25 MHz so including a suitable guard band the result is similar at (2 times) 1.5 MHz.

These figures are sufficient to offer a basic service and provide coverage. It is the need to provide additional capacity which drives up the amount of spectrum required. In the case of both GSM and CDMA it is possible to use smaller and smaller cells to ensure that there is sufficient capacity in each cell for the traffic it encounters. This would require, however, existing cells to be replaced by smaller ones, as opposed to overlaying smaller cells on top of the existing larger ones. This is because there would be insufficient frequencies to introduce a micro-cell inside any given cell as all possible alternative frequencies are being used in adjacent cells. Obviously replacing each cell by a number of smaller ones, instead of overlaying smaller cells, is significantly more costly. **We understand there is a limit to which one can split cells in a macro-cellular architecture in CDMA. This is due to the fact that the minimum inter-site distance between CDMA base-stations is limited by interference and pilot pollution. This limits site density in CMDA**. GSM does suffer from this limitation to quite the same degree, meaning that for a network with limited spectrum in hot-spots GSM operators have an advantage over CDMA operators in their ability to implement smaller and smaller cell-sizes.

The impact of having more spectrum available is to make it easier and cheaper to add additional capacity into areas that are already covered. This is a commercial decision and a thorough cost-benefit analysis would be required for any given set of circumstances (area to be covered, traffic density, technology employed, cost of new sites etc) to produce meaningful results.

Our analysis has therefore focussed on how much spectrum has been assigned to existing operators to determine the minimum which an operator has been prepared to accept and then establish commercial services. In this way, we rely on the operators themselves to have made the appropriate cost-benefit decisions and identify international best practice in terms of minimum spectrum allocations.

GSM

As identified above, the theoretical minimum for a GSM network is (2 times) 1.5 MHz, however at a blocking probability of 2% (a typical quality of service goal for most operators) this would only provide 7 traffic channels and thus 2.9 Erlangs of capacity in each cell. A typical user generates 0.015 Erlangs of traffic and hence the cell could support around 193[11] subscribers. In all but the most sparsely populated rural areas, this is unlikely to be sufficient to provide a commercially viable service. Doubling the available spectrum to 3 MHz provides 15 traffic channels per cell, giving 9 Erlangs of capacity and thus supporting 600 subscribers. This is a more realistic figure, and in addition, the availability of the additional channels will simplify frequency planning, making the network more practical to roll-out. Therefore, whilst the theoretical minimum is 1.5 MHz, an allocation of 3 MHz would appear to be a more practical minimum.

The Swiss operator Orange has been allocated (2 times) 2.2 MHz at 900 MHz and (2 times) 24.8 MHz at 1800 MHz[12]. However the GSM Forum indicates that Orange Switzerland is only operating an 1800 MHz network[13] and has not rolled-out any 900 MHz coverage at all. This would suggest that (2 times) 2.2 MHz is insufficient GSM spectrum in which to roll-out a service, or at least it is not viable

[11] This could be increased by the use of the Half Rate Codec.

[12] Source: www.ero.dk/gsm

[13] Source: http://www.gsmworld.com/roaming/gsminfo/net_chor.shtml

to use such a small amount when a much larger amount of 1800 MHz spectrum is available. It is also worth bearing in mind that in a country such as Switzerland where many of the major cities are close to international borders, the availability of the spectrum will be further reduced due to the need to co-ordinate with neighbouring countries.

In France, Bouygues Telecom has been allocated (2 times) 3.2 MHz at 900 MHz and (2 times) 23.2 MHz at 1800 MHz. However, in contrast to Orange Switzerland, they are operating a dual-band 900/1800 MHz network. France is also a larger country with fewer critical international borders than Switzerland, hence the availability of the 3.2 MHz will be greater throughout most of the country.

We can therefore deduce that the minimum amount of spectrum in which a GSM operator can establish a commercially viable service is between 2.2 and 3.2 MHz which fits in with our initial assumption that a figure around (2 times) 3 MHz would be a practical minimum. Note, however, that in both these examples, the operator concerned had a large amount of 1800 MHz spectrum available to them, hence the decision as to whether a service in their limited 900 MHz spectrum would have been feasible will have been impacted by the availability of the 1800 MHz spectrum.

The smallest amount of spectrum allocated (in Europe) to an operator in a single band, is to Mobitel in Bulgaria, who have only (2 times) 4.6 MHz at 900 MHz for their national service. This is because the military are still big users of spectrum and have not yet vacated the 900 MHz band, nor much of the 1800 MHz band. It is planned, however, that once military services have been removed from these bands, more spectrum will be made available to Mobitel (and other Bulgarian operators).

CDMA

A single CDMA (1x) carrier in a suitably planned network can deliver around 20 to 25 Erlangs of capacity[14] and thus support around 1,500 subscribers. As highlighted above, providing additional capacity in hot-spots would require the network to be redesigned to make each cell smaller. As with GSM it is much more feasible to do this by the addition of further channels, however given CDMA's capacity advantage over GSM it does appear feasible, at least in theory, to operate a service in just (2 times) 1.5 MHz.

The number of channels available impacts the ability of the network to expand and deal with traffic and coverage

1 channel (2 times 1.25 MHz) will allow a single layer only; a hierarchical cell structure is not feasible in this case

2 channels gives room for a two-layer structure, e.g. a macro cell layer together with either a micro-cell or pico-cell layer

3 channels allows the deployment of a complete hierarchical cell structure where the traffic demand is high or a mix of layers such as on macro cell and two micro-cells

[14] Source: http://research.microsoft.com/asia/dload_files/group/wireless/2002p/RichYao1.pdf

4 channels allows increased flexibility and additional capacity.

In a response to the Hong Kong government consultation on 3G spectrum[15], the manufacturer Lucent said that in their view, 3 channels provide sufficient spectrum for an operator to commence a service. 3 channels can be accommodated in 3.75 MHz of spectrum, though with appropriate guard-bands this increases to 4 MHz. While this relates directly to the Hong Kong market, there are similarities between the dense urban areas in Hong Kong and those in the major metros in India.

Evidence suggests, therefore, that an allocation of (2 times) 4 MHz for CDMA is the minimum required to allow a commercially viable service to be rolled-out.

Geographical restrictions

Geographical restrictions on licences typically arise from two possible sources:

there are existing users of the spectrum allocation in some areas of the country (who will either move at a later date or will form an ongoing restriction)

the regulator believes that regional licences are more in keeping with policy objectives than a nation-wide licence.

The following table focuses on those countries where the amount of spectrum allocated is particularly small, or where there has been a significant movement in the amount of spectrum which has been allocated over time. The table illustrates the initial frequency allocations to various operators (excluding those in India) plus their final allocations in instances where we are aware that additional spectrum has been allocated.[16] It additionally indicates the geographic coverage of licences.

Country	Operator	Technology	Service	Initial Allocation	Final Allocation	Area
Nepal	UTC	CDMA 1900	WLL	2 x 10 MHz		Kathmandu Valley
	NTC	CDMA 1900	WLL	2 x 10 MHz		Rural areas only
	NTC	CorDECT	WLL	1 x 20 MHz		Rural areas only
Pakistan	Telecard	CDMA 1900	WLL	2 x 5 MHz	May be increased to 10 MHz	Nation-wide
Sri Lanka	Lanka Bell	CDMA 1900	WLL	2 x 3.5 MHz		Nation-wide
USA	Various	CDMA 1900	Cellular	2 x 10 to 2 x 20 MHz		Regional
Hong Kong	Orange	CDMA 800	Cellular	2 x 7.5 MHz		Island-wide
Poland	Centertel	GSM	Cellular	2 x 4 MHz @ 900 (+ 2 x 9.4 MHz @ 1800)	2 x 8 MHz @ 900 (+ 2 x 9.4 MHz @ 1800)	Nation-wide
Bulgaria	Mobitel	GSM	Cellular	2 x 4.6 MHz		Nation-wide

Contiguous band-planning

If an operator is allocated spectrum which is not in contiguous blocks, measures need to be taken to protect the edges of those blocks from interference from and to other operators (assuming that spectrum is interleaved between various

[15] Source: http://www.ofta.gov.hk/3g-licensing/3G-consultation-lucent.pdf

[16] In addition, in Pakistan, the government has just announced the auctioning of 2 further cellular licences. Of these, one is at 1900 MHz and comprises 2x5 MHz.

operators). In the 1999 UK Monopolies and Mergers Commission inquiry into the cost of calls to mobile phones, Cellnet commented[17]

"Cellnet and Vodafone have 23.5 MHz in three non-contiguous bands, compared with Orange and One2One who have 30 MHz in a single band. The effects of this on network costs are particularly acute in city areas…"

In the UK for example, because of the way in which the frequencies for the GSM operators were handed out, Cellnet and Vodafone have ended up with three non-contiguous blocks, one in the E-GSM band, one in the standard GSM band and one at GSM 1800. The situation in countries such as France and the Netherlands, where spectrum was auctioned in 5 MHz blocks is even more pronounced with some operators having 4 or more non-contiguous blocks of spectrum.

The technical impact of such non-contiguity is to require, in many cases, filters at the cell-sites to block out signals from other operators. Even where filters are not required, there will be a need for co-ordination of frequency use between operators, or alternatively a guard band between operators (reducing the utility of the spectrum). Depending on how discontinuous the spectrum allocations are (and especially what other services are interleaved), the impact of non-contiguous spectrum will vary, however in general it is better for an operator to have a single block of spectrum than many separate ones.

Conclusions

We have shown that the absolute minimum amount of spectrum that is required in order for an operator to roll-out a commercially viable service is around (2 times) 3 MHz for GSM and (2 times) 4 MHz for CDMA. However it is important to note that these minimum amounts do not allow for additional capacity to be implemented when traffic demand rises, and there are limits (particularly in the case of CDMA) as to how small cells can be split to offer additional capacity in hot-spots.

Mechanisms for Refarming Spectrum

Reallocation of bands where there are no users is straightforward, in the sense that the management of incumbent users does not have to be considered. However, reallocation typically involves either relocating users or imposing technical constraints on incumbents' use to allow the sharing of bands. Traditionally, relocation of incumbents has been done by giving users notice that they will have to vacate bands or adopt new equipment well in advance of the reallocation date. Other approaches that have been tried and/or proposed include

giving incumbents relatively short notice periods

compensation of incumbents by newcomers. This may involve new entrants' "buying out" incumbents or making arrangements to share spectrum with them.

setting up a national spectrum fund to pay incumbents to move quickly. The fund could be financed through licence fees or central government revenues.

[17] Cellnet and Vodafone, Monopolies and Mergers Commission, 1999.

spectrum pricing

spectrum trading.

Short notice periods

While in principle short notice periods might seem sufficient, they can be difficult to implement in practice even when twinned with the offer of spectrum in less congested bands. Incumbents may have significant investments in equipment which will be stranded by such decisions and, whether this is the case or not, they are likely to claim this is so in consultation. Approaches which offer incumbents some financial incentive to move – either carrots (i.e. payments) or sticks (higher spectrum fees in congested spectrum) – have therefore been considered by some regulators.

Compensation of incumbents

Incentives for incumbents to move may be given by issuing overlay licences in which the licensees are assigned a block of spectrum with existing licensees as sitting tenants. The new licensees may then buy out their sitting tenants. This approach has been used for example in Australia, Italy, New Zealand, Canada and the US. The issues that need to be considered in granting overlay licences are

the rights of incumbents to interference protection

the duration of incumbents' licences

the new entrants' rights to interference protection

the grounds on which the new entrant may ask the incumbent to vacate the spectrum.

Economic analysis suggests that giving new entrants a right to move incumbents with compensation, and/or giving incumbents a time limited right to stay is more efficient than simply giving incumbents a perpetual right to stay. This means the new entrant is faced with the cost of relocation but is not held up to indefinite negotiations with incumbents trying to extract the full value of the spectrum.[18]

In practice overlay licences the following features

incumbents' rights are time limited

incumbents have a right to compensation from the new entrant if asked to leave before their licences have expired

new entrants must offer incumbents the same interference protection as they had originally

new entrants are similarly given the same level of protection from interference as other site licensees in the band.

The creation and auction of overlay rights is clearly feasible and provides a pragmatic response to the issue of migrating incumbents. Encumbered spectrum

[18] Efficient Relocation of Incumbents, P Cramton, E Kwerel, J Williams; University of Maryland and the FCC. October 1996.

is likely to be valued less than unencumbered spectrum, but the discount can be limited by giving incumbents time limited rights.

An alternative approach which often occurs when government users, and in particular the military, are to be relocated is that the new licensees simply pay a fraction of the costs of moving the incumbent. For example, in some countries (e.g. France and Egypt) release of the GSM1800 band for mobile services was secured once payments had been made to the incumbent military users.

In the US there are formal processes for reimbursement of federal users (by commercial users) when federal users are required to move frequency band or geographic location.[19] At present these only apply to four frequency bands – 216-220 MHz, 1432-1435 MHz, 1710-1755 MHz and 2385-2390 MHz. Federal users are required to submit estimates of the marginal costs of relocation to a comparable facility in advance of the spectrum being auctioned and there are rules for negotiation over payments and other terms between auction winners and the incumbent federal user.

Spectrum funds

A spectrum fund has been introduced for example in Hungary, in France[20] and in Japan. In France the government temporarily subsidises migration of users to new bands but the new users of the band pay these costs in time through a payment that is additional to the standard spectrum fee. This approach has the advantage of not unduly burdening the new users of the band with a large initial cost, but has a cost for the French tax payer (i.e. the cost the "loan" to the new users). Japan has an intermediate approach in which new users pay at least 50% of the cost of moving incumbent users and the remainder is funded by spectrum licence fees collected by government.

General issues to be considered with regard to spectrum funds are

the need to determine what constitutes fair compensation and related to this having a time limit on incumbents' eligibility for payments so they do not hold out for very large payments

the possible need for appropriate government approval to spend the money, implying that the availability of funds for reallocation purposes may not be relied upon

the possibility of using earmarking some of the revenues raised from spectrum licence fees for a spectrum fund.

Spectrum pricing

Spectrum pricing in congested bands could be used to encourage users to move to less congested bands which have a low or no spectrum price. This could be done by setting the price at or close to the value of the spectrum to the incoming use. This assumes that the incoming use has a higher value of spectrum than the incumbent use. This approach has been used in the UK (see chapter 4)

[19] Mandatory Reimbursement Rules for Frequency Band or Geographic Relocation of Federal-Dependent Systems, NTIA, June 2002.

[20] Final Report on The Detailed Spectrum Investigation Phase III, 862-3400 MHz, European Radiocommunications Office, April 2000; Refarming and Secondary Trading in a Changing Radiocommunications World, ECC Report 16.

Spectrum trading

Spectrum trading gives licensees rights to trade their assignments much as one might trade other resources, such as land or mineral rights. The implementation of spectrum trading is complex. In terms of refarming, trading allows third parties to buy out incumbent users and thereby potentially change the use of the spectrum. This approach can work in practice if licensees have blocks of spectrum whose use can be changed without breaching national or international allocation regulations. In cases where there are many small users with localised or point-to-point assignments then trading is not likely to be feasible as a means of refarming spectrum because of the costs of co-ordinating and negotiating with many small users.[21]

In the case of government users, the issue of what happens to the money received from the spectrum trade needs to be considered. If all the money reverts to the finance ministry then the licensee will have no incentive to trade.

In those countries that have introduced trading (Canada, the US, Australia, New Zealand and Guatemala) there have been few instances where trading has resulted in refarming of spectrum. The only examples we are aware of involve trading that allowed the amalgamation of private mobile radio licences into blocks of spectrum that could be used to provide public mobile services.[22] This has been done in Australia and the US. But these are mature markets and so may not provide suitable models for the Indian context. Due to the complexities and wider implications of spectrum trading, we would suggest that this issue needs to be decoupled from the present consultation on spectrum policy. The issue of trading should be taken up separately.

Summary

As the value of spectrum continues to increase the issue of spectrum refarming will grow in importance. Regulators around the world are increasingly looking at ways to achieve timely refarming of spectrum so that new services can be deployed quickly and the economic and social benefit from use of the spectrum is maximised. The need to give incumbent users financial incentives to move out of the spectrum has been widely recognised and number of different approaches are being used internationally including government or industry funded subsidies, overlay licences, spectrum pricing and spectrum trading. There is no single approach that will work well in all bands – the technical characteristics of spectrum use and the number and identity of users are all relevant to the choice of approach. We suggest that TRAI considers these options in the Indian context so that spectrum can be readily released for high value applications, such as mobile telephony.

Conclusions

In summary the main conclusions from this chapter are

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[21] In this instance "hold-out" problems can arise where one or a small number of users demand very high payments so that a block of spectrum can be cleared for a new use/user.

[22] Reported in "Implementing Spectrum Trading", Radiocommunications Agency, UK, July 2002.

The absolute minimum amount of spectrum that is required in order for an operator to roll-out a commercially viable service is around (2 times) 3 MHz for GSM and (2 times) 4 MHz for CDMA. These minimum amounts do not allow for additional capacity to be implemented when traffic demand rises..

We have proposed three possible mechanisms for identifying additional frequencies for CDMA services in India. A summary of these proposals is given below. None of these proposals provides immediate, obviously clear spectrum for CDMA services, however the latter of these options offers the greatest potential for CDMA services whilst remaining technology neutral towards GSM 1800 operators.

Proposal	Result	Pros	Cons
Superposition of CDMA 1900	2 x 20 MHz	Implementable immediately No impact on 1800 MHz services. Only a small impact on 3G services. 1900 MHz spectrum provides compatibility with international market.	Provides lowest amount of spectrum of all proposed solutions. Possible interference problems with existing DECT/corDECT systems. Small reduction in future 3G spectrum.
Superposition of CDMA 1700	2 x 30 MHz	Implementable immediately (subject to possible re-tuning of existing 1800 MHz networks). Provides almost equal allocations for CDMA and mobile/WLL services. No impact on existing DECT/corDECT services or future 3G services. No need for re-assignment of spectrum.	1700 MHz spectrum only compatible with South Korean services implying higher infrastructure/handset costs. Currently no 800/1700 dual-band handsets, so roaming (either overseas or between Indian networks) is severely restricted.
Alternative band plan	2 x 40 MHz	Provides almost equal allocations for CDMA and mobile/WLL services but greater than previous option. 1900 MHz spectrum provides compatibility with international market.	Proposed 3G allocation would (at the present time) be India specific.

The need to give incumbent users financial incentives to move out of the spectrum they occupy has been widely recognised and a number of different approaches are being used internationally including government or industry funded subsidies to move, overlay licences, spectrum pricing and spectrum trading.

There is no single approach to spectrum refarming that will work well in all bands – the technical characteristics of spectrum use and the number and identity of users are all relevant to the choice of approach. We suggest that TRAI considers these options in the Indian context so that spectrum can be readily released for high value applications, such as mobile telephony.

Changing allocations over time

Initial allocations

In most countries the concept of allocating an initial amount of spectrum to an operator and then increasing it at a later date has not been normal practice. Operators have typically received the full amount of spectrum they are to be allocated in a specific band at the time they are first awarded a mobile licence (though parts of the spectrum may have been unusable until existing users migrated). The common exception to this rule has been where the regulator has wished to open up a new band (such as GSM 1800), or where a long-term programme of re-farming has meant that some part of an existing band which was previously used by other users has been vacated. In these instances the regulator has a number of options

offer the spectrum to the incumbent cellular operators

tender the spectrum through auction or a beauty contest (in this case, the incumbent cellular operators may or may not be allowed to bid for the new spectrum)

a combination of the two above methods.

The approach taken depends primarily on whether or not the regulator is seeking to increase competition in the mobile market by licensing additional operators. This in turn will depend on the number of incumbents, the potential size of the market and current market penetration. Examples of approaches taken elsewhere are given in the box below.

Size and timing of increments

When it comes to enhancing capacity, the increments of spectrum which would be useful are, in essence, the same as those required in the absolute minimum situation, as the addition of this much spectrum allows an additional 'layer' on the network providing greater flexibility in planning but also allowing capacity to be installed at a lower cost. The increment should therefore be around 1.5 MHz for GSM operators and 1.25 MHz for CDMA operators. Clearly anything less than 1.25 MHz for a CDMA operator is of no benefit as the channel bandwidth is 1.25 MHz. For GSM, the addition of smaller blocks than around 1.5 MHz do not provide sufficient additional spectrum to allow any significant improvement in network design. For example, if a single (200 kHz) channel were given to a GSM operator, that channel would be virtually useless except in isolated locations, as in order to re-design the channel plan of a whole network just to accommodate a single additional channel would be extremely costly for little additional yield in network performance.

Examples of approaches to spectrum assignment

UK

2 operators allocated GSM900 spectrum (incumbent telco and one other)
2 further operators licensed using 1800 MHz spectrum (in a beauty contest)
remaining 1800 MHz spectrum was allocated to all four operators, once it was decided that no more operators would be licensed
Australia
2 operators allocated GSM 900 spectrum (incumbent telco and one other)
auctions of 800 MHz, 1800 MHz and 2GHz spectrum on a technology neutral basis in which incumbents and new entrants could bid. Incumbents had a tighter cap on the amount of spectrum they could win than new entrants.

Netherlands

2 operators allocated GSM 900 spectrum (incumbent telco and one other)
government attempted to allocate part of 1800 spectrum to one further licence to new entrant but was challenged on the grounds of artificially restricting the number of licences as more spectrum was available[23]. An auction of all 1800 spectrum was held in which incumbents as well as new entrants could participate and this resulted in a total of five operators.

Pakistan

2 operators allocated (2 x 10 MHz) 800 MHz spectrum (one chooses AMPS, the other D-AMPS)
2 operators allocated (2 x 10 MHz) GSM 900 spectrum
The AMPS operator migrates to E-GSM (part in existing spectrum plus 10 MHz of E-GSM spectrum in exchange for returning 10 MHz of 800 MHz spectrum)
Existing GSM operators (not E-GSM operator) return (2 x 2.4 MHz) 900 MHz spectrum to make way for new licensees in return for which they receive (2 x 6 MHz) 1800 MHz spectrum.
Government auction 3 new licences, only 2 of which will be awarded – 2 including both (2 x 4.8 MHz) 900 and (2 x 8.8 MHz) 1800 MHz spectrum and 1 with (2 x 5 MHz) of 1900 MHz spectrum

There is, however, a strong argument that spectrum should not be given to operators in a piecemeal fashion, but should, instead, be allocated in larger blocks. Whilst the addition of a small amount of spectrum will, in most cases, be beneficial, re-designing a network which had, say 4 channels, to now have 5, requires a significant amount of effort in terms of cell planning and re-engineering (which involves significant capital investment). To then increase the channels from 5 to 6 requires a similar amount of effort and cost again. Likewise from 6 to 7 and so on. **Conversely, if an operator is given a larger increase in spectrum, the cell planning and re-engineering can be done in one hit.**

[23] This contravened European legislation, namely the Mobile Directive 96/2/EC.

Additionally, if an operator knows, that it will receive additional spectrum at some future point, and what that spectrum will be, its use can be taken into account in the initial network design, further reducing downstream re-engineering costs.

The biggest factor in all the above consideration is timing. If an operator knows the timetable for the allocation of spectrum that will be made available it can plan accordingly. Otherwise at each new addition of spectrum the costly re-engineering task needs to be conducted.

If an operator were to roll-out a service using the minimum possible spectrum, it would soon reach a point whereby cells start to become saturated with traffic. In these circumstances the operator would have no option but to reduce cell sizes. It is at these times that additional spectrum becomes a critical factor in decision making. Reducing cell-sizes is costly, in some cases whole sites need to be re-located and additional sites added. If, on the other hand, the operator has access to additional spectrum, an existing site can be expanded with the addition of new transceivers to increase its capacity. Minimum spectrum allocations are therefore only really suited to the very early years of an operator's existence. Without additional spectrum soon thereafter, the cost of provision of additional capacity will escalate to the point where it no longer becomes economically viable for an operator to install additional capacity and thus it must cease new subscriptions or raise prices to discourage usage. This is clearly counter-productive if the intention is to have a thriving competitive mobile telecoms environment.

Criteria for additional assignments

As described above, with limited spectrum availability there reaches a point where it becomes uneconomical for an operator to continue to roll-out additional capacity and the lack of spectrum will block the development of a thriving mobile market. With the Indian market being characterised by metropolitan hot-spots of very large potential traffic, the point at which it becomes uneconomical to roll-out additional capacity in these hot-spots will be reached even with low market penetration.

It would be difficult to propose suitable criteria for further spectrum allocations as demonstrating that it is necessary can be complex. Fundamentally the necessity arises when the commercial situation of the company using the spectrum is such that they are no longer able to provide additional capacity or connections, however in reality there is a point which occurs significantly before this where the availability of additional spectrum would facilitate a different and lower cost investment strategy and network design. The point at which these decisions need to be taken cannot necessarily be indicated by traditional criteria as a number of factors will come into play. What is most important is that the operator knows in advance when spectrum will become available, and how much will become available.

Conclusions

We conclude that the regulator should assign all the available spectrum to existing operators if it is satisfied that the market is sufficiently competitive (so that new operators do not need to be licensed). This has the following benefits it allows operators to more economically deploy their networks with consequent benefits for consumers in terms of lower prices

it reduces administrative costs for operators and the regulator

it removes the regulator from having to make often arbitrary decisions about how much spectrum to release initially.

It promotes the effective use of spectrum, as leaving spectrum fallow is clearly not effective use.

It is therefore unusual internationally for a regulator to leave vacant spectrum unassigned when the future use of the spectrum is known (as is the case for frequencies allocated to 2G and 3G mobile services), and especially for telecommunications services where public policy is directed towards to ensuring low-cost services for all.

Assignment mechanisms

Introduction

Historically, in most countries radio frequencies were assigned on a first come, first served basis or were reserved for use by specific, often public sector, users. In recent years, increasing demand for radio spectrum has made it necessary to ration the most sought-after spectrum, including spectrum used by mobile operators. Two principal approaches have been adopted to rationing the spectrum, namely administrative selection, based on either first come first served or comparative selection approaches, and market-based selection, using auctions and trading.

The approach taken in India to assigning spectrum to mobile operators has involved auctions followed by an administrative process for determining whether licensees have a "need" for additional spectrum based on their subscriber numbers. Spectrum charges are set as a percentage of AGR and are related to spectrum bandwidth . The combination of a needs assessment together with spectrum charges linked to revenues would appear to give some assurance that spectrum is used reasonably efficiently, in a technical and an economic sense. However, discrimination in spectrum allocations between operators on the basis of technology, as a means of compensating for differences in the spectral efficiency of different technologies, could potentially undermine these efficiency benefits.

In this chapter we describe options for assigning and pricing additional spectrum for mobile services and assess their pros and cons. We also discuss the role of spectrum caps.

Administrative selection

Administrative processes involve one or more of the following

beauty contest

first come, first served

first come, first served together with other criteria (e.g. an assessment of "need", non-discrimination requirements)

administrative pricing.

Beauty contest

Beauty contests (or comparative tenders) involve licences being assigned by the regulator to the "best qualified" of the competing applicants. Key issues in the design of these procedures are the criteria used to choose the winning applicant, the precision and transparency of the criteria (i.e. publication in advance of the tender), the weighting given to different criteria and the transparency of reasons for the final decision.

Beauty contests have frequently been used to assign new mobile licences, however, they are not typically used to assign additional spectrum to existing licensees. Possible reasons for this include

regulators' views that all operators should have roughly the same spectrum for reasons of competitive equality

the difficulties in determining appropriate criteria for comparing applicants.

The latter problem arises because the additional spectrum is normally used to accommodate traffic growth at locations already receiving a service rather than to extend roll-out or provide new services. As this is the situation that applies in India there is no obvious criterion for choosing between applicants. We therefore do not consider beauty contests any further.

First come, first served (FCFS) approach

The FCFS approach works best when the demand for spectrum is unlikely to exceed the available supply, however the approach is sometimes used where spectrum scarcity exists. For example, FCFS is typically used to assign spectrum in bands for point-to-point links and private mobile radio, both of which tend to involve many small users of spectrum, often with bespoke spectrum requirements and whose demands can change from year to year. In these circumstances, FCFS provides a flexible approach to assigning spectrum with low transaction costs compared with the alternatives of auctions or beauty contests, however, it has the downside that users have no incentive to use spectrum efficiently. On the contrary they have incentives to hoard spectrum as this has no cost.

FCFS on its own is not appropriate for mobile spectrum because it does not provide a means of dealing with simultaneous competing claims from numerous operators that are likely to exceed the available spectrum resource.[24] Hence, in the case of mobile spectrum, there needs to be a mechanism for deciding between competing demands for the spectrum. Assuming this is not done in an arbitrary manner then criteria for choosing between users need to be determined. In principle the spectrum could be rationed by the regulator setting a price that equates demand and supply, mimicking what happens through an auction or trading, though this is difficult to achieve in practice. Below we discuss how the regulator might set prices that ration spectrum demand and provide incentives for efficient spectrum use and the role technical efficiency criteria and non-discrimination requirements can play in determining the assignment of spectrum to competing users.

FCFS plus a non-discrimination requirement

Most regulators have a statutory duty or function to facilitate or promote competition, and the TRAI is no exception. This duty is often interpreted as requiring that competing operators have access to essential facilities and other key resources, such as numbers and spectrum, on non-discriminatory basis. Assigning all operators the same amounts of spectrum, or comparable amounts if the propagation characteristics of bands differ significantly, meets non-

[24] Unlike private mobile radio and fixed links demand is not intermittent.

discrimination requirements. It facilitates competition by giving all operators the same or a similar starting position.

Non-discrimination requirements would also suggest that different technologies should compete on a level playing field. This means that technology should not be a criterion when deciding the amount of spectrum to assign to a given operator. A technologically neutral approach to spectrum assignment will promote adoption of the technically most efficient technology. If alternatively operators are assigned different amounts of spectrum based on the spectral efficiency of the technology they deploy, then they will have no incentive to adopt the technically most efficient technology. The adoption of a technologically neutral approach to spectrum assignment would therefore seem to be consistent with the TRAI's function in respect of efficient spectrum use.

In some countries a technology neutral approach has been achieved by auctioning the spectrum in blocks that are not associated with any particular technology (e.g. Australia, Canada, the United States), although the frequency band in part defines the technology that can be used. For example, there is simultaneous deployment of two or more of CDMA, TDMA D-AMPS and GSM technologies in a number of countries including: Australia, Argentina, Brazil, Chile, Canada, China, Thailand and the United States.

FCFS plus a technical efficiency requirement

The basic aim of technical efficiency measures is to provide objective quantitative measures of the efficiency with which the spectrum is used. The idea being that by rationing spectrum based on operators' achievement of an efficiency target a regulator can ensure that users do not hoard spectrum and are using it effectively. However there are measurement problems in their application.

There was some interest in some European countries in the mid to late 1990s in using technical efficiency criteria as the basis for making spectrum assignments to mobile operators in the context of reassigning frequencies from analogue to cellular networks (e.g. Finland[25] and Sweden). However, we are not aware of the use of technical efficiency measures in respect of the subsequent release of 1800 MHz spectrum in Europe. The emphasis has been on assigning 1800 MHz spectrum in a transparent manner that best promotes competition in mobile markets, either through beauty contests or auctions. As discussed below technical efficiency measures do not meet this requirement.

Measurement issues

There are no universally agreed measures of what constitutes efficient use of spectrum. Often, for mobile networks, metrics such as erlangs/MHz or erlangs/MHz/km^2 have been used to determine the efficiency of the throughput of the network for a given amount of spectrum. These measures do not indicate spectrum efficiency per se, but do give an indication of whether the spectrum is being used effectively. Such measures are typically used to provide a comparison between the performance of two different networks or standards, rather than an absolute measure of the spectral efficiency itself. The results will

[25] The measure used was traffic density in busy hour Erlangs per bandwidth per square kilometre.

vary across an area of coverage as there is a direct relation between cell-size (and installed capacity on those cells) and the capacity that can be provided in any particular region. Further, changes in the amount of spectrum allocated to an operator could also change the outcome. Operators allocated a small amount of spectrum will, by default, be forced to install a lot of small cells and hence will have a high capacity for a given amount of spectrum. However, this will have been achieved by increased investment a factor not addressed in such measures.

There are a number of practical matters with the use of technical efficiency measures that need to be considered. For example

how are peak flows (which determine spectrum requirements) to be taken into account in average throughput measures?

how are differences between operators in service availability and other aspects of service quality to be taken into account?

if traffic is not measured *in situ* what models are to be used?

These and other issues are addressed later in this report where we conclude that any findings in respect of spectral efficiency depend on the measure chosen and the actual real world implementations (as opposed to the results of theoretical models).

Implications for economic efficiency

Even if technical efficiency can be adequately defined and measured (and we doubt this), achievement of technical efficiency does not equate to the achievement of economic efficiency. Most regulators seek to make the most economically efficient use of spectrum and we would expect TRAI also to seek to promote this objective.

Ignoring economic factors can lead to false conclusions on spectrum efficiency. Increased technical efficiency can be achieved by simply reducing the spectrum available to operators however this comes at the cost of increased investment and so potentially higher costs for end users. Such an outcome does not best contribute to the growth of telecoms services, particularly if there is unused spectrum that could be assigned to reduce operators' infrastructure costs.

Conclusions

In summary, we conclude that technical efficiency measures are not an appropriate basis for determining spectrum allocations. It is important that economic as well as technical efficiency needs are considered if TRAI's recommendations are to result in "the efficient management of available spectrum" and "promote efficiency in the operation and the growth of telecoms services".

Administered incentive pricing

Introduction

Under the FCFS approach users have incentives to hoard spectrum and have no incentive to use it efficiently, because there is no or little cost to having more rather than less spectrum. Spectrum pricing, and administered incentive pricing in particular, addresses these deficiencies by facing users with the opportunity cost of the spectrum they use.

Administered incentive prices (AIP) are prices charged to spectrum licensees that are set by the regulator and are intended to reflect the opportunity cost of spectrum use i.e. the opportunities forgone from using the spectrum in its current use. Economic theory shows that opportunity cost prices provide appropriate incentives for efficient use of spectrum.[26] AIP are normally applied to spectrum that has not been auctioned.

There are a number of ways in which AIP may promote efficiency

it can promote an efficient assignment of spectrum between users i.e. for low value users to give up spectrum in favour of higher value users

it can give users incentives to adopt more spectrally efficient technology

it can give users incentives to move to less congested frequency bands

it can discourage hoarding by giving users an incentive to maximise the use of their spectrum.

In practice the nature of these incentives depends on the constraints faced by different spectrum users. In the case of mobile services, pricing will ensure that spectrum licences are not held by operators that value the spectrum less than the AIP, and so will promote efficient assignment of spectrum between operators.

Mobile operators cannot move to other less congested frequency bands (unlike say fixed link users) in response to pricing, though their technology choices may be guided by spectrum pricing to the extent that they have the option to use more spectrum or adopt a technology that makes more efficient use of the spectrum (e.g. EDGE in GSM networks). In practice the latter choice may not be available.

Mobile operators have strong financial incentives to maximise the use of their spectrum regardless of whether it is priced or not, assuming greater use is associated with increased profits. This seems a likely outcome in India given competitiveness of the mobile markets, as indicated by the large number of competitors relative to numbers found in other countries.

So in summary AIP can provide incentives for efficient spectrum use by mobile operators though the incentives may be weaker than for other uses of spectrum where users have more options to change their spectrum use. AIP have been implemented in the UK, Australia and proposed in New Zealand for mobile services. Elsewhere, in cases where spectrum has not been auctioned, governments have often set relatively large fees for cellular operators that in some cases are related to the amount of spectrum assigned to the operator. While it could be argued this helps promote efficient use of spectrum, the values are not set at a level which is explicitly intended to achieve efficiency objectives.[27]

[26] See “An Economic Study to Review Spectrum Pricing”, Indepen, Aegis Systems and Warwick Business School, February 2004. www.ofcom.org.uk

[27] For a review of approaches in European Union countries which reaches a similar conclusion see “Study on administrative and frequency fees related to the licensing of networks involving the use of frequencies, Aegis Systems and Connogue, Report for the European Commission, November 2001.

Below we describe the main elements of the approaches to AIP used in the UK, Australia and proposed in New Zealand for cellular services, and consider their relevance to India.

UK

AIP in the UK are set based on the opportunity cost of the spectrum. This opportunity cost is estimated as the additional cost (or cost saving) to an average or reasonably efficient user as a result of being denied access to a small amount of spectrum (or being given access to an additional small amount of spectrum).[28] The additional cost (cost saving) depends on the application and is calculated as the estimated minimum cost of the alternative actions facing the user. These alternatives may include

investing in more/less network infrastructure to achieve the same quantity and quality of output with less/more spectrum

adopting narrower bandwidth equipment

switching to an alternative band

switching to an alternative service (e.g. a public service rather than private communications) or technology (e.g. fibre or leased line rather than fixed radio link).

Prices of spectrum should be a function of the spectrum use denied to other users and this depends on the bandwidth used and the geographic area over which use is denied i.e. the area sterilised by the service. If spectrum is shared between a number of users then the price should be pro-rated according to each users' share of the spectrum used. Prices should only apply in bands and locations where spectrum is congested i.e. where demand exceeds the available supply. Almost all spectrum assigned to mobile operators is congested.

In the case of cellular mobile services opportunity cost values were calculated by Smith-NERA in 1996[29] based on the cost of building additional base stations in place of additional spectrum to meet traffic growth. More recently opportunity cost values for cellular have been estimated by Indepen et al (2004) based on the infrastructure costs an operator might be save if assigned an additional 2 x 2.4 MHz of spectrum (the equivalent of a single channel per sector assuming a four-cell per cluster, three sector per cell network configuration).

The values obtained are shown in the following table together with the actual prices paid. The actual prices paid are significantly lower than the opportunity cost estimates. This is because the Government decided to halve the opportunity cost values and then prices were set based on an average standard tariff unit (STU) for all mobile services (including private mobile radio, public access mobile radio and cellular services) of £1.65/MHz/km^2. The licence fee is then set as follows: STU x bandwidth x area x modifier.

[28] See Indepen et al (2004)

[29] Study into the Use of Spectrum Pricing, NERA and Smith System Engineering, Radiocommunications Agency, April 1996.

A modifier was applied to give GSM 1800 operators a discount based on the argument that 1800 spectrum has inferior propagation in rural areas and so 1800 operators incur higher expenditure on infrastructure in these areas.[30] We note this argument has now lost its force given that operators have fully built out their networks and spectrum at 1800 MHz offers the advantage of greater reuse (compared with 900 MHz spectrum) to meet demand in "hotspots".

Table 2: Mobile Opportunity Cost Values for a 2x1MHz National Channel

	Smith-NERA (1996)	**Indepen et al (2004)**	**Prices currently charged**
Cellular – 900 MHz	£1.63m	£1.68m	£0.72m
Cellular - 1800 MHz	£0.81m	£1.68m	£0.55m

Source: Indepen et al (2004)

Australia

Charges for the use of spectrum licensed under apparatus licences are set based on three elements: an administrative element to recover direct administrative costs; a Spectrum Maintenance Cost (SMC)[31] to recover indirect spectrum management costs; and the Spectrum Access Tax (SAT) which is based on the perceived value of the spectrum denied to other users. The latter is imposed to encourage efficient use of spectrum and to provide a return for the Government for the use of a valuable community resource. The SAT is based on the following formula:

SAT = K x (S, G) x B X A

Where K is an arbitrary constant

(S, G) is a weight related to the spectrum location (S) and the geographic location (G) of the licence

B = bandwidth

A = coverage area of the licence

The formula has been criticised by the Australian Productivity Commission on the grounds that[32]

it is inflexible, in that it cannot readily respond to changes in congestion and does not reflect variations in congestion between different uses in different parts of the spectrum plan

there is lumpiness in the fees because location and bandwidth ranges are used in the formula

the geographic weights reflect transmitter location and not transmission areas, where the latter is a better measure of spectrum denial

[30] See Report on Modifiers to be used in determining Administrative Pricing Fee Charges for Mobile Services, Radiocommunications Agency, 1998.

[31] This is set at 39.78% of the Sat for all licences.

[32] Radiocommunications, report no 22, Productivity Commission, 2002, AusInfo, Canberra

the K factor is opaque.

As a consequence the regulator is currently reviewing its approach to spectrum charges.

In practice the approach just described does not apply to spectrum used by mobile operators. There is no SAT applied to mobile licences awarded by auction after 1992 and for licences awarded before 1992 the SAT is based on the annualised value of auction prices for comparable spectrum. This is termed "shadow pricing" of spectrum. Issues with this approach are that

auctions of comparable spectrum only happen intermittently and raising charges based on result auctions held at the height of the dotcom boom, as happened in Australia, could result in over pricing and inefficiency

licensees need to be informed in advance of the circumstances under which their spectrum charges will be increased (as decreases seem unlikely in practice), as this risk will need to be built into their business plans.

The Australian Productivity Commission therefore recommends that application of shadow pricing "should be undertaken in a transparent and predictable manner that incorporates necessary adjustments to make comparisons meaningful".[33]

New Zealand

The New Zealand government has recently commissioned advisers to develop a methodology for determining prices for spectrum licences used by broadcasters and mobile operators that are due to expire in 2010.[34] The prices are to be based on a transparent formula and to reflect a fair market value for the spectrum.

The proposed approach involves taking the original auction prices paid for the spectrum and increasing these by the rate of growth in net cash flows over time. A number of simplifying assumptions are made to obtain a constant growth rate for net cash flows equal to the assumed rate of revenue growth. In the case of cellular services this approach is not appropriate because the market is not sufficiently stable to assume a constant or even logarithmic growth rate for net cash flows. It has therefore been concluded by advisers reviewing the original proposals that a full market valuation of the cellular operators is required to derive a value for the spectrum.[35]

Conclusions on AIP

What measure?

Spectrum has value for two reasons – it reduces the costs of producing a given service and it generates rents (or super-normal profits) for licensees. The UK approach to valuing spectrum described above captures the value associated

[33] Recommendation 8.6, Radiocommunications, report no 22, Productivity Commission, 2002, AusInfo, Canberra

[34] See "Development of Price Setting Formulae for Commercial Spectrum Rights at Expiry, Covec for the Ministry of Economic Development, October 2003. The New Zealand government has decided to offer renewal options to the licensees five years in advance of the expiry date.

[35] "Review of Proposed Price Setting Formula", Pricewaterhouse Coopers for the Ministry of Economic Development, November 2003

with the reduction in production costs for a marginal MHz of spectrum, and so may be below the efficient price. The Australian and New Zealand approaches capture both the rent and the cost reduction elements for all of the spectrum used by an operator, not just the marginal MHz, and so are likely to exceed the efficient price.

In practice there are good reasons to err on the low side, so as to ensure spectrum is not left idle and so we suggest that the UK approach is more appropriate than the approaches suggested in Australia and New Zealand.

Impact of AIP

The impact of spectrum pricing in the UK on incentives to economise on spectrum and in moving spectrum from low to high value users is generally thought to have been small.[36] This is likely to be because the values were set at a low level relative to the estimated opportunity cost values. In Australia there is has not been any attempt to assess the impact of AIP though it has been noted that in their current form AIP could in principle distort spectrum use.

More generally, the impact of AIP on users' costs will depend on market conditions and how they react to the prices. If they economise on spectrum use then the effects on costs and so prices in downstream markets are likely to be small. If users do not greatly economise on their spectrum use then the following effects can be expected

in perfectly competitive markets the increase in costs will be passed on in final user prices

in imperfectly competitive markets the increase in costs will be partly passed on and "rents"[37] otherwise earned by shareholders will be reduced

for non-commercial/public sector users the additional costs will need to be funded either by government or from economies elsewhere in the organisation.

Relevance to Indian Mobile Sector

The current charges for mobile spectrum in India are not directly related to the value of spectrum use denied to others. Charges increase with bandwidth only if revenues also increase with bandwidth occupied. The link between revenues and the amount paid suggest the intention is to recoup some of the value of licences (i.e. the "rent" earned) rather than simply to promote efficiency. As there is still currently excess demand for mobile spectrum the price is clearly not at a level that rations supply and demand. In fact we observe that it is very difficult if not impossible for any administrator to set a price that perfectly rations supply and demand – only market determined prices set through auctions or trading can achieve such an outcome. To illustrate this we note that in the UK it appears that prices have been set at too low a level to achieve efficiency objectives, whereas in France the government initially set prices for 3G spectrum at too high a level and there were no bidders for the licences.

[36] Indepen et al op. cit.

[37] Rents or supernormal profits arising from use of free or low cost spectrum will be earned if the market is imperfectly competitive.

Hence pricing is unlikely to effectively ration demand for the spectrum though it may provide efficiency incentives. Other mechanisms are required, such as the non-discrimination requirement discussed above, in order to determine the amount of spectrum to assign to different operators.

Market selection

Auctions

International experience

Auctions have been used in India to assign mobile licences. It is generally argued that auctions have advantages compared with beauty contests of transparency, promoting economic efficiency and economic welfare[38], and giving the state a fair return for the use of a public asset.[39] Auctions can however have some disadvantages. There is a risk that they will be designed solely to maximise government revenues and that government will seek to inflate prices by creating an artificial scarcity of spectrum (e.g. by withholding spectrum).

Critics of auctions of mobile licences have also argued that

high upfront fees create a barrier to entry and/or effective competition

incumbents and large operators have significant advantages under an auction approach because of their “deep pockets”

roll-out will be delayed because operators do not have the funds for network investment and/or because the cost of financing has risen significantly

industry consolidation, and hence reduced competition, will be a consequence of the auctions

end-users will pay higher prices as operators seek to recover auction payments.

The impact of auctions on user prices is a matter of debate. Some economists have argued that auction payments are sunk costs and so will not affect operator behaviour i.e. prices will not increase and roll-out will not be delayed. Others have argued that large auction payments have increased the risk of bankruptcy and so the cost of debt for mobile operators, and hence final prices will be increased and investment could be reduced. Empirical analysis of this issue using US data suggests that auction payments do not lead to increased prices for mobile services.[40] From an operator perspective beauty contests may appear more attractive than auctions because smaller sums are paid for licences. However, McKinsey (2002)[41] has shown that comparative tenders can place equally onerous financing obligations on operators through coverage and roll-out commitments made by operators in their licence bids. This in turn suggests that any impact on final prices is likely to be similar for auctions and beauty contests.

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[38] Well-designed auctions should result in licences being assigned to the most efficient operator. Also auctions are a more efficient (i.e. less distorting) way of raising government revenues than most forms of taxation.

[39] See for example McMillan J (1994), Why Auction the Spectrum?, Telecommunications Policy, November 1994.

[40] See “Spectrum auctions do not raise the price of wireless services: Theory and evidence, Evan Kwerel, Federal Communications Commission, October 2000.

[41] McKinsey (2002), Comparative Assessment of the Licensing regimes for 3G Mobile Communications in the European Union and their Impact on the Mobile Communications Sector, Report for the European Commission, 25 June 2002`

The experience of the 3G auctions in Europe shows that tender outcomes do not appear to have been greatly affected by whether an auction or a comparative tender was used. In particular, new entry, number of bidders, licences left unassigned and licences subsequently returned seem to be unaffected by the choice of tender format. The main difference appears to be that global and regional operators are more likely than local operators to win licences in auctions (as compared with comparative tenders).[42] This may suggest that players with deeper pockets are more likely to win auctions or that licences are more valuable to operators with a global or regional footprint.

Relevance to India

Auctions have been used extensively to assign new mobile licences and could in principle be used to assign additional spectrum to existing or new licensees. The practicality of this depends on whether new licensees would be permitted to bid and, if new licensees were not permitted to bid, whether bidders could acquire a number of spectrum lots.

To see this consider the following simple example. Suppose there are 6 licensees eligible to bid for 6 identical blocks of spectrum and each bidder is only permitted to win one block, then obviously no-one will bid more than the reserve price. Alternatively if two of the licensees are only interested in 2 of the blocks of spectrum, because of the particular technology they use, and four licensees are interested in the other four blocks then the same problem arises. However, if each bidder is allowed to win 2 spectrum blocks then there will be competition for the spectrum – 3 bidders could potentially finish up with no spectrum. The same result will apply if the number of blocks of spectrum is less than the number of bidders and again one or more bidders may finish up with no additional spectrum. Clearly auctions will only work if the TRAI is prepared to allow for the possibility that some of the existing operators will not receive additional spectrum, because it is won by either a new operator (assuming new licensees are eligible to bid) or other incumbent operators.

However, in the Indian context it can be reasonably said that there is enough competition in mobile markets and no new entrants are expected to come in. Therefore, the demand for additional spectrum will only be from the existing operators. For reasons of non-discrimination and to ensure the continued viability of existing operators it would not be desirable for only some operators to be assigned additional spectrum. Therefore, equal assignments together with administrative pricing, decided by a clearly defined and transparently adopted formula is preferable to auctions.

Spectrum Trading

International experience

Spectrum trading has been introduced for some parts of the spectrum in Australia, Canada, New Zealand, Guatemala and the US, and is expected to be introduced in the UK in 2005. The details of the trading arrangements

[42] Lessons from 3G Licensing, Indepen Working Paper, 2002

implemented differ between these countries, however, in all cases licensees are allowed to aggregate, divide, transfer and lease spectrum.

The main argument for introducing spectrum trading is that it promotes economic efficiency. In particular, it is argued that by making rights tradable users have financial incentives to economise on spectrum use, spectrum will be reassigned to the highest value users and, if change of use is permitted, spectrum will be reallocated to the highest value use of spectrum in a timely manner. To realise the efficiency benefits from trading there needs to be careful consideration of the definition of rights and their duration, the institutional arrangements for making trades, the information available to all parties and the safeguards on anti-competitive behaviour. It can take several years to put appropriate arrangements in place, in part because of the time taken to convert existing licences to tradable ones and to put the national database of assignments in a form that can be accessed by licensees wishing to trade.

The experience of spectrum trading has recently been reviewed by the UK Radiocommunications Agency, the Productivity Commission in Australia and the Ministry of Economic Development in New Zealand. These reviews indicate that the volumes of trades have been small in all countries. Reasons for this include

The tenure of licences is not judged to be long enough to warrant trading (Australia)

Licensees acquire spectrum in order to build communications networks that have a relatively long life and so are not interested in trading for some time (general)

There have been regulatory impediments to making trades (the US)

There is ready availability of spectrum through spectrum auctions (New Zealand)

Technology specific licences are not amenable to trade (apparatus licences in Australia)

There has been a lack of publicly available information that would be helpful to parties seeking to make trades (Australia and New Zealand).

Relevance to India

Spectrum trading provides a mechanism for reassigning spectrum that the regulator has already assigned. It cannot deal with the issue of how to assign vacant spectrum to mobile licensees and is not therefore of immediate relevance to the TRAI's review.

However, looking to the longer-term spectrum trading could offer considerable benefits and should be considered by TRAI as a possible direction for future spectrum policy. For example, mergers and acquisitions are relatively straightforward if spectrum licences are tradable (subject to competition concerns) and users would have greater flexibility in making small changes in their spectrum use.

Spectrum Caps

International Experience

Explicit caps on the spectrum a mobile operator may acquire in a specific auction have been applied in a number of countries, including Australia and New

Zealand, and a cap on aggregate spectrum holdings of mobile operators has been applied in the US. The latter involved a 45 MHz cap in metropolitan areas and a 55 MHz cap in rural areas. In all cases these caps are intended to address concerns that an organisation may seek to acquire spectrum to monopolise the downstream mobile communications market.

The alternative to spectrum caps is for the regulator or the competition authorities (depending on who has authority over competition issues in this area) to undertake case-by-case competition assessments of spectrum acquisitions.

The advantage of spectrum caps is that they provide certainty to operators and allow rapid and low cost approval/veto of spectrum acquisitions. The disadvantage is that they are inflexible, potentially permitting problematic transactions and blocking transactions that would be in the public interest.

In the US, the FCC reviewed these arguments in 2001 and in doing so took into account the degree of competition in mobile markets. The FCC concluded that it "should move from the use of inflexible spectrum aggregation limits to case-by-case review of spectrum aggregation".[43] The limits lapsed in January 2003.

In Australia, the Productivity Commission recommended that the spectrum limits applied in auctions should be repealed in favour of case-by-case review under competition legislation. The Government did not accept this recommendation.[44]

In the UK Ofcom is proposing to rely on use of its general competition powers in respect of spectrum trades.[45]

Relevance to India

Caps of 2x15 MHz and 2x12.4 MHz on mobile operators' spectrum holdings have been recommended by the TRAI as part of their guidelines on the treatment of intra-circle mergers and acquisitions. In addition the TRAI has recommended a minimum number of operators per circle (3) and that if mergers breach certain market share limits then a detailed examination of the competition impacts of the merger would be undertaken.

The TRAI's analysis of competition issues leads to its recommendations on the minimum number of operators/circle and the need for detailed investigations in certain circumstances. In these circumstances spectrum caps play a useful role in ensuring that operators compete on a similar basis in respect of their spectrum holdings.

Conclusions

In summary the main conclusions from this chapter are

FCFS, beauty contests and spectrum trading are not suitable for assigning additional spectrum to mobile operators

Technical criteria such as erlangs/MHz or erlangs/MHz/km^2 have been used to determine the efficiency of the throughput of the network for a given amount of

[43] para 6, 2001 Biennial Regulatory Review Spectrum Aggregation Limits for Commercial Mobile Radio Services, FCC 18 December 18, 2001 WT Docket 01-14.

[44] The Productivity Commission's Radiocommunications Inquiry Report, Government Response, 2002.

[45] "Ensuring effective competition following the introduction of spectrum trading", Ofcom, 10 June 2004.

spectrum. These measures do not indicate spectrum efficiency per se, as the results depend on the coverage area and the amount of spectrum allocated to an operator. Operators allocated a small amount of spectrum will, by default, be forced to install a lot of small cells and hence will have a high capacity for a given amount of spectrum. However, this will have been achieved by increased investment a factor not addressed in such measures.

Technical criteria are also flawed in principle as they do not promote economic efficiency

Administered incentive pricing, set on a clearly defined and transparent basis, may have a role in promoting efficient spectrum use although we note that the incentives for mobile operators are weaker than for other users with fewer constraints on spectrum use and mobile operators have strong financial incentives to maximise the use of their spectrum regardless of whether it is priced or not, (given that greater use is associated with increased profits).

Administered incentive pricing is not sufficient as a mechanism to ration spectrum between competing operators for the simple reason that the regulator will not be able to set the "right" price to perfectly ration demand. However, we have suggested that in the Indian context mobile operators should each receive equal amounts of spectrum.

The TRAI should apply non-discrimination principles when deciding how much spectrum to assign to different operators. This means assignments should be technology neutral.

Auctions could provide an effective means of assigning additional spectrum in circumstances where the number of bidders (be they just incumbents or incumbents and new entrants) is likely to exceed the number of spectrum lots available. But this seems unlikely to occur in India in which case auctions are not an appropriate allocation method.

In developing spectrum policy for the longer term the TRAI should consider the possibility of implementing spectrum trading arrangements in the future..

Spectrum Efficiency

Introduction

This chapter begins with an exploration of the theoretical measures which are commonly employed to measure spectrum efficiency, and describes the way in which, when applied to real-world installations the measures become so complex that the results lose meaning.

A comparison between GSM and CDMA is used to illustrate the results of each possible measure.

Calculating Spectrum Efficiency

The sections below describe the steps in calculating spectrum efficiency for GSM and CDMA systems. We start by describing the theoretical framework.

Theoretical efficiency measures

Technical spectrum efficiency metrics focus on the ability of a certain amount of spectrum to carry a certain throughput of information. Shannon, states that the ultimate information-carrying capacity of a band-limited communications channel varies in proportion to its bandwidth and also as a function of the signal to noise ratio (S/N) within the channel. Given signal power S, total-received-noise power N, and channel bandwidth B (hertz), Shannon's theorem[46] provides this upper boundary for the capacity C of a digital channel in bits per second:

$$C = B\log_2\left(1+\frac{S}{N}\right).$$

This is the theoretical maximum capacity which any channel can support, however it is, in practice, impossible to achieve (and one key element is determining what the signal to noise ratio is as this will vary significantly depending on system design).

A GSM channel has a bandwidth of 200 kHz and the design S/N ratio is typically 17dB. Thus the theoretical maximum throughput of the system is 1,134 kbps. For CDMA the bandwidth is 1.25 MHz but the S/N ratio is around 8dB. Thus the theoretical maximum throughput for a CDMA channel is 3,585 kbps. However in real life, the Shannon limit is almost impossible to achieve. Other factors such as the need to restrict emissions in neighbouring frequencies, and the need to ensure that a radio connection can be maintained over a channel that is subject to reflections and fading caused by the movement of the subscriber mean that some bandwidth or S/N must be traded for the impact of the real world.

A more practical measure of the efficiency of any given technology is to consider its throughput in bits per second per Hz (b/s/Hz). This offers a measure of the bandwidth efficiency of any given technology or scheme.

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[46] Shannon, C.E., "Communication in the Presence of Noise," Proceedings of the Institute of Radio Engineers, Volume 37, No. 1, January 1949, pgs 10 to 21

Taking GSM, the transmission rate is 270 kbps which fits into a 200 kHz channel, making the bandwidth efficiency 1.35. For CDMA, the effective throughput for each user is 19.5 kbps and the channel bandwidth is 1.25 MHz, therefore the bandwidth efficiency is only 0.0156. However we must take into account that in the case of GSM, only one user can occupy the available bandwidth, whereas for CDMA multiple users can access the same spectrum. If we take into account the process gain for CDMA of 64 (ie allowing 64 users to share the same spectrum) the bandwidth efficiency rises to 0.998. Thus we could argue that GSM is more spectrally efficient than CDMA.

The above bandwidth efficiency calculations, however, apply to one cell only, in a situation where there is no interference and take no account of the efficiencies of the technologies themselves. To make a like-for-like comparison between these two technologies we must compare them on the basis of their capability to support a given level of traffic. This is typically measured in Erlangs[47] per MHz.

As CDMA (1x) operates in a bandwidth of 1.25 MHz, we shall take this as our base-line for comparison.

GSM

We shall begin with GSM as this is the easier calculation. For GSM, 1.25 MHz allows 6 carriers. Each carrier provides 8 traffic channels, however common practise is to use 1 traffic channel per 2 carriers to provide control signals. Thus these 6 carriers can support 45 traffic channels (plus 3 control channels). At a blocking probability of 2% (a typical level set by both operators and regulators), these traffic channels would support 35 Erlangs of traffic. A typical user generates 0.015 Erlangs of traffic so this spectrum can support 2,333 users.

This assumes that the each GSM channel is being fully utilised for a voice (or data) call. However, voice traffic is not constant in that there are large pauses between speech. The typical duty-cycle of voice traffic (ie the proportion of time that a person actually speaks) is around 40%[48]. GSM employs a scheme known as discontinuous transmission (DTX) whereby when there is no voice traffic on a given channel, no transmission is made (either from the base station or the mobile). This has the effect of freeing the mobile channel for another user and the added bonus of increasing battery life for the handset and reducing interference between cells. However GSM voice is circuit switched, that is to say that the information is carried across a circuit established for the duration of the conversation. Whilst DTX can ‘punch holes’ in this circuit, it could not be re-assigned to an alternative voice conversation as there is a high probability that both users may wish to speak simultaneously. The holes are, however, ideal for carrying traffic of a bursty nature, such as IP data traffic. Thus DTX in itself does nothing to improve the throughput of GSM.

In addition, GSM has the option to chance the voice coder used. The normal full-rate (and enhanced full-rate) voice codecs produce data at a rate of 13 kbps (the

[47] A dimensionless unit of the average traffic intensity (occupancy) of a facility during a period of time, usually a busy hour. Erlangs is expressed as the ratio of (a) the time during which a facility is continuously or cumulatively occupied to (b) the time that the facility is available for occupancy.

[48] C. B. Southcott et al. Voice control of the pan-European digital mobile radio system. In IEEE GLOBECOM, November 1989

GSM channel rate is 22.8 kbps – the remainder of the capacity is used for error protection). The half-rate codec produces data at 5.6 kbps (the half-rate capacity is 11.4 kbps – the remainder again used for error protection). Using the half-rate codec allows each GSM traffic channel to be split into two and thus carry twice the number of calls. The impact of the use of this codec is a reduction in speech quality. In our example above, the number of available traffic channels doubles from 45 to 90 providing a throughput of 78.3 Erlangs (and supporting 5,220 users).

CDMA

The cell capacity of a CDMA system is dependent on the bandwidth used the process gain and the allowable error rate. Since the capacity of a CDMA system is dependent on the noise tolerance of data if we assume an Eb/No of 8dB this will give a bit error rate (BER) of ~0.006 which is acceptable for voice communications. The capacity of a single cell CDMA system can be calculated using the equation[49]:

$$N = \frac{G}{d}\left[\frac{N_o}{E_b}\frac{W}{R} - \frac{n}{S}\right] + 1$$

Where:

G is the antenna sectorisation (1 in this instance)

d is the voice duty cycle (1 in this instance)

Eb/No is the energy per bit to noise ratio (8dB)

W is the total transmission bandwidth (1.25 MHz)

R is the base band bit rate (19.5 kbps)

n/S is the ratio of received thermal noise to user signal power (assume this is zero for now)

For these parameters N (the number of simultaneous users) is 11, indicating that 11 users could simultaneously use the channel at this level of error rate. With a blocking probability of 2%, this channel will therefore support 5.8 Erlangs of traffic or 386 users. However unlike with GSM, the fact that the voice duty cycle is only 40% has an impact on the capacity of a CDMA system as the silent times, detected by a technique known as voice activity detection (VAD) can be re-used for other calls. In addition, a CDMA cell can be sectored (usually into three 120 degree areas), but this can not be done for GSM as the frequencies can not be re-used in an adjacent cell. Whilst sectorisation splits a cell into three cells, there is inevitably some overlap between the cells due to imperfect antenna patterns and the actual increase in capacity from a 3 sector cell is nearer 2.5 than 3.

Taking these two factors into account, N becomes 64, a significant increase in throughput providing 53.4 Erlangs and thereby supporting 3560 users. This figure is very sensitive to the Error rate, however. Increasing the BER to ~0.023, representing an Eb/No of 6dB, the throughput of the system nearly doubles to 103, providing 90.9 Erlangs and supporting 6060 users. However at this BER,

[49] http://www.skydsp.com/publications/4thyrthesis/chapter3.htm

speech quality will suffer due to the number of received errors (voice communication typically requires a BER of less than 0.01).

Multi-cell environments

The next stage in this analysis is to consider geography. So far we have looked at a single cell, however we are trying to provide coverage over a wider area. This is where the real capacity gains of CDMA come into play. For CDMA systems the same frequencies can be re-used in each cell, whereas for GSM, protection needs to be given between cells to combat interference. For CDMA the interference from neighbouring cells reduces the capacity of the cell. The calculations[50] are complex but typically the capacity of the cell is reduced by a factor of between 2 and 2.5. For the sake of this analysis we shall assume that the worst case reduction of 2.5, thus in the multi-cell situation, the capacity of a single cell is 25 calls, providing 17.5 Erlangs (and supporting 1,166 subscribers).

The standard design parameter for GSM is that the signal to interference (S/I) ratio should be 17dB if good voice quality is to prevail. However, users are used to higher voice qualities and S/I ratios of nearer 21dB are increasingly the norm[51]. To achieve this requires a frequency re-use factor of 7 (a tessellated hexagon pattern), though a re-use factor of 9 is often used in dense urban areas due to the increased interference from the close proximity of neighbouring cells.

Assuming a frequency re-use factor of 7, the 1.25 MHz of spectrum we used for the initial analysis does not support 1 cluster of cells, as 7 times 200 kHz (1.4 MHz) is required. If we increase the spectrum allowed for the GSM analysis to 1.4 MHz to take account of the re-use issue, there is sufficient spectrum for a single channel in each cell, providing 7 traffic channels. At our 2% QoS figure, this provides 2.9 Erlangs of traffic, supporting only 193 subscribers. Using the half-rate codec, this rises to 8.2 Erlangs (546 subscribers).

The table below summarises the figures produced in this analysis.

Measure	GSM	CDMA	unit	Notes
Bandwidth efficiency	1.35	0.998	bits/s/Hz	
Capacity in 1.25 MHz	35		Erlangs	GSM Full-rate codec
with 2% QoS	78		Erlangs	GSM Half-rate codec
Capacity in 1.25 MHz		5.8	Erlangs	Raw CDMA
with ~0.006 BER		53.5	Erlangs	CDMA with sectoring and 40% duty cycle
Capacity in 1.4 MHz	2.9		Erlangs	GSM Full-rate codec, re-use factor of 7
with 2% QoS	8.2		Erlangs	GSM Half-rate codec, re-use factor of 7
Capacity in 1.25 MHz		17.5	Erlangs	CDMA with sectoring and 40% duty cycle
with ~0.006 BER				Multi-cell situation

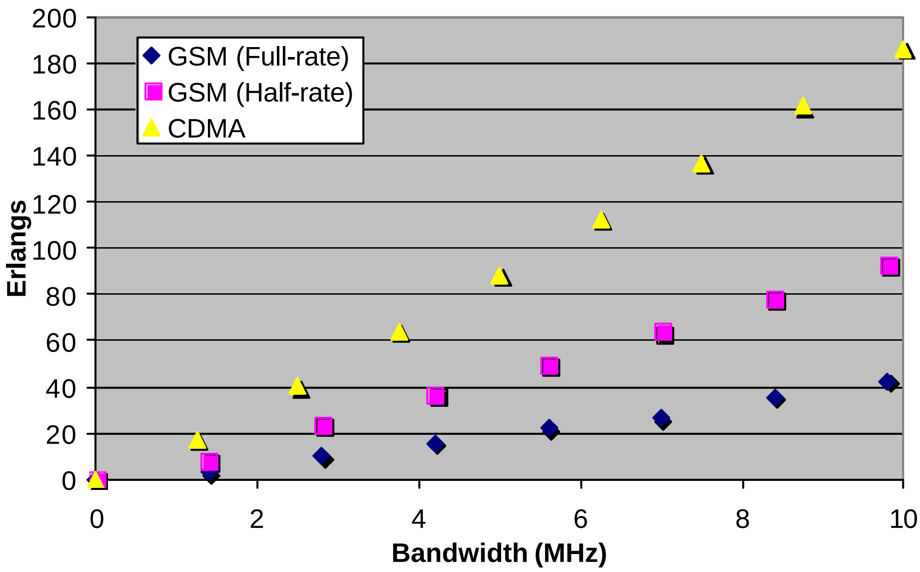
Thus if we take the bandwidth efficiency as our measure, GSM is more spectrally efficient. If we compare raw single-cell CDMA with single-cell GSM, GSM is more efficient. If we compare CDMA with sectored cells and VAD (Voice Activity

[50] http://www.ittc.ku.edu/~rvc/documents/865/865_cdmacap.pdf

[51] Is it time to rethink frequency reuse formulas? Rudokas, R and T. Benz

Detection) in a single-cell environment to GSM, GSM with half-rate codec is more efficient than CDMA, whereas GSM with full-rate codec is less efficient.

In a multi-cell environment, which more reflects the real world, CDMA appears up to 6 times as spectrally efficient as GSM (with full-rate codec). The analysis of GSM capacity, however, is unfair, as we are considering the minimum number of channels that could be provided. As we expand the available spectrum the capacity rises in a non-linear fashion. As the amount of spectrum rises for a CDMA system, intercell interference can be traded off against capacity, however for the sake of this analysis, we will consider that for each additional 1.25 MHz available to a CDMA system, each frequency is re-used in each cell. The following chart illustrates the capacity in Erlangs that each technology achieves in bandwidths of between 0 and 10 MHz.



It can clearly be seen that, largely due to the use of voice activity detection with CDMA, the throughput of a CDMA system compared to GSM in the equivalent amount of spectrum is around 4 times (and not 6 times) higher, and only twice as efficient as GSM with half-rate codec.

The real world

These analyses are idealistic in that no account has been taken of the real-world situation, in particular interference from other cells. The situation is further confused in the CDMA case by the use of variable rate voice codecs which can adapt to the channel circumstances, increasing or lowering the bit rate they use dependent on the level of interference and the quality of the channel. A similar concept, the Adaptive Multi-Rate Codec (AMR) is being developed for GSM.

Inter-cell and intra-cell interference pose a great challenge to CDMA system coverage and capacity performance. The interference in CDMA systems is highly dynamic, due to both changing user profiles and the local environment. A combination of multi-user interference, narrow band and wide band interference are major considerations in determining the forward and reverse links performance of CDMA systems. Unlike for GSM systems where estimation of mean signal levels was enough to determine best server coverage thresholds, CDMA systems quality of service (QoS) and capacity performance are interference driven, making coverage and capacity mutually non-exclusive. In other words, interference in a CDMA system changes with traffic loading to the extent that overload control thresholds are predefined in the planning process. Whilst it is sufficient to use link budgets to estimate cell size for initial planning, the criteria for actual network dimensioning will be bounded by the traffic demand density, range limitations due to the mobile transmit power ceiling and interference conditions.

One possibility would be to model a given mobile network and ascertain how effectively it employed the spectrum it had been given. For example, the peak throughput[52] of the network in a given area could be compared to the spectrum available to give a real-world Erlang/MHz/area measure. However such an analysis would be flawed:

Depending upon the area that was selected for the analysis, the result would vary significantly. Dense urban areas would produce significantly different results to rural areas. Even defining the boundary of an area could have a significant impact, as traffic (and thus the calculated efficiency) is not constant, even between neighbouring cells.

The quality of service delivered in a given area needs to be considered. The throughput of traffic is not the only measure which is important, especially if there is excess demand that is not being met because of congestion.

Operators with less spectrum will have been forced to implement very small cell-sizes and thus will appear more spectrally efficient in such a simple model, however this does not take into account the significant additional cost they may have incurred compared with an operator with more spectrum available.

Modelling of networks is useful in an engineering context to assist operators in planning and designing their networks but is not useful as a regulatory tool. Small changes to the input variables will have a significant impact on the output and thus the results are too sensitive to input assumptions to provide a solid and useable result..

Cell densities

There are no international standards for cell densities in either CDMA or GSM networks. Cell densities will be a determined by factors such as population density, availability of spectrum, frequency band in use and technology employed. The required cell density is an input to the coverage planning exercise and is based upon the estimated cell capacity, traffic density and link performance.. Though there are no standards for cell densities, international experience has shown that cells can only be shrunk to certain sizes before increasing the density any further falls foul of the law of diminishing returns. For a CDMA network, cell sites can not be placed less than around 500 metres apart due to the interference caused by mobiles from one cell into the other, even when the power control has set the power to an absolute minimum. For GSM, cells can be placed no less than around 200 metres apart. Using cell densities as any measure of spectral efficiency leads to an irresolvable circularity with the output

[52] Or an average over a 24 hour or some other period.

parameters directly affecting the input parameters. As a regulatory measure it is therefore highly flawed

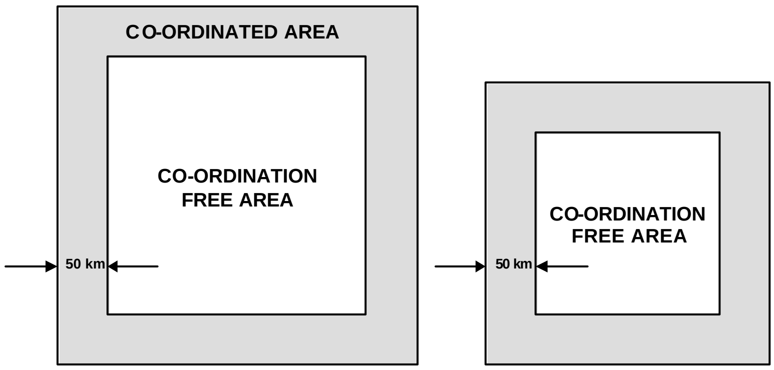
The Impact of Restricted Allocations

In each instance that a spectrum allocation borders geographically with another allocation, there is a need to co-ordinate the services in the two allocations across the border area. Such co-ordination can be handled in two fundamental ways:

An agreed channel plan whereby each operator agrees which channels they will use in the border areas (typically 50% of channels are used by one operator and 50% by the other, however this can vary if one operator is known to have higher traffic levels than another)

Bi-lateral co-ordination whereby individual sites and channels are co-ordinated between operators. This produces more effective spectrum usage as often less than 50% of channels are lost but requires a large amount of co-ordination between operators which can be very time-consuming and costly, in addition to which it makes re-engineering the network more difficult.

In either instance, the utility of a given spectrum assignment in the border areas is reduced by up to 50%. For a typical mobile network, the area over which co-ordination or channel planning need to take place to prevent interference is up to 50 km from the border itself.



The diagram above clearly illustrates the impact of co-ordination. The smaller the total area over which the licence is allocated, the greater the percentage of that area is reduced in utility by the need to co-ordinate. In the co-ordinated areas there is effectively less spectrum available (to operators on both sides of the border) therefore reducing the borders by way of allocating licences over larger geographic areas makes more efficient and effective use of the available spectrum.

Similar, but less severe restrictions occur if spectrum in a given geographic area is shared between a number of operators, as opposed to fewer operators. At the edge of each assignment, a small guard-band is usually left to simplify the design of cell-sites. Each guard band eats into the available spectrum in the same way that the co-ordinated area eats in to the utility of the spectrum when operators border. The restriction is less severe, however, because the guard bands are typically very small in comparison to the overall allocation (200 kHz for GSM for example).

To maximise the efficiency of use of any block of spectrum, it should be allocated for use in as wide an area as possible, thereby minimising the effect of the restrictions imposed around the borders of the allocation. In addition, it is technically more efficient to allocate a block of spectrum to one operator rather than split it between multiple operators. However, this ignores economic considerations, in particular the desire to promote competition.

Conclusions

In summary, the conclusions from this chapter are:

there are a number of potential spectrum efficiency measures which can be applied to any given technology

comparisons between GSM and CDMA show that depending upon which measure is taken, either system can be shown to be more spectrally efficient.

real-world implementations have a significant impact on the ability of theoretical measures to provide meaningful results

modelling of networks is too sensitive to the input assumptions to be valuable as a regulatory tool

restrictions on allocations, particularly on a geographical basis, reduce the ability to use the spectrum efficiently due to the reduced utility of the spectrum in border areas.

ASSOCIATION OF UNIFIED TELECOM SERVICE PROVIDERS OF INDIA

RESPONSE TO

TRAI CONSULTATION PAPER

ON

Spectrum Related Issues.

Efficient Utilisation, Spectrum Allocation and Spectrum Pricing

Consultation Paper No.11/2004 dated 31st May 2004

INDEX

AUSPI RESPONSE TO CONSULTATION PAPER ON SPECTRUM RELATED ISSUES

Chapter 2: Current spectrum availability and requirement

(i) ***Should the 450 MHz or any other band be utilised particularly to meet the spectrum requirement of service providers using CDMA technology?***

CDMA operators world-over are utilising at least 10+10 MHz to 20+20 MHz on an average 15+15 MHz spectrum per operator to meet their requirement to provide various services on their networks deploying CDMA technology. In this connection please refer to Annexe – I. In contrast in India, actual allocations to CDMA operators are maximum 2.5 MHz spectrum initially.

CDMA operations in India is in the frequency band 824 – 844 MHz paired with 869 – 889 MHz which is inadequate. This band allows only 20 MHz spectrum with only 14 carriers for use by CDMA operators as against internationally accepted 800 MHz standard of 25 MHz spectrum in the 824 – 849 MHz band paired with 869 – 894 MHz.

The spectrum requirement of CDMA operators in India is to be made closer towards international requirements of 10+10 MHz to 20+20 MHz average of 15+15 MHz / operator.

We should, therefore, look for additional appropriate spectrum to meet the requirement of service providers using CDMA technology. The spectrum so chosen should be in the bands in line with international practices so that the operators do not face problems relating to the availability of equipment and the handsets which are compatible with the existing networks. The frequency band chosen should not pose any problem in international roaming as well. The operators also should not be left at the mercy of one or two vendors in world market otherwise cost effectiveness will be lost.

CDMA operators are using 800 MHz and 1900 MHz bands wherever they are operating. Please refer to Annexe – II. The 1900 MHz band referred to here is also known as US PCS band (1850 – 1910 MHz paired with 1930 – 1990 MHz). In all countries except Korea CDMA technology uses either 800 or 1900 MHz band. The Korean PCS band is (not standard DCS 1800 MHz band) not suitable for India amongst many other reasons the important ones being one or two vendors making equipment and handsets in this band, FDD spacing different and unique, no compatibility with 800 MHz band being used in India, no dual mode / multimode 800 MHz/KPCS even after 8 years or so of its implementation in Korea. In India the requirements of additional spectrum for CDMA network should be in this 1900 MHz US PCS band.

This US PCS band or 1850 MHz – 1910 MHz paired with 1930 MHz – 1990 MHz is proposed due to the following important reasons amongst many other reasons.

- In consonance with ITU-R regulation.
- Multiple vendors of infrastructure throughout the world and also a number of handset vendors.

- Compatibility of handsets and infrastructure equipment between 800 / 1900 MHz in CDMA network.
- Dual band handsets and infrastructure equipment are internationally available with many vendors in 800/ 1900 MHz band.
- International roaming feasible with 800/ 1900 MHz (i.e., US PCS band), as majority of the CDMA networks internationally are there in these bands.

450 MHz band (452.5-457.5 MHz paired with 462.5-467.5 MHz) available for mobile services is only 5 MHz and is not sufficient. This band is being considered only in far flung rural areas. However, AUSPI recommends 450 MHz band be utilized as a complement and not as a substitute to 1900 MHz US PCS band.

It is proposed that apart from existing spectrum, further requirement for CDMA be made in the following bands. This is in line with the ITU-R Recommendations and permits flexibility and use of different bands as relevant here & elsewhere. It would ensure that CDMA Operators can co-exist and compete on a fair basis with other technology operators.

- 1850-1880 MHz p/w 1930-1960 MHz (2 x 30 MHz) for CDMA (B3).
- 1900-1910 MHz p/w 1980-1990 MHz (2 x 10 MHz) for CDMA (B3).
- 1755-1805 MHz p/w 2110-2160 MHz (2 x 50 MHz) for Equal spectrum for CDMA and GSM (B5).
- 452.5 – 457.5 MHz p/w 462.5-467.5 MHz (2x5 MHz) for CDMA.

The above suggestions will:

- Ensure effective and efficient global sourcing of equipment and handsets leading to cost reduction and availability of voice and broadband services to the masses at affordable price;
- Provide adequate bandwidth for the growth of CDMA mobile services in the country;
- Ensure the most efficient and optimal utilization of spectrum;
- Ensure level playing field between GSM and CDMA operators, thus ensuring technology neutral approach of the Government.

(ii) ***The consultation paper has discussed ITU method for assessment of spectrum requirement. Based upon the methodology submit your requirement of spectrum for next 5 years. While calculating the required spectrum, please give various assumptions and its basis?***

It is projected by different market analysts that the Indian telecom market will exceed 200 million wireless subscribers in the next 5 years i.e. by 2009. Out of this, we expect that about 50% of the market will be with CDMA operators, i.e. ~100 million. **Each operator will require 20+20 MHz of spectrum in the appropriate bands over a period of 5 years.**

[Market research data: Evli Bank plc have projected a figure of 109 million CDMA subscribers by 2010. Ernst & Young have estimated 142 million wireless subscribers by 2007. ABTO (now AUSPI) had projected 18 million CDMA subscribers by March '05].

(iii) ***Whether IMT 2000 band should be expanded to cover whole or part of 1710 – 1785 MHz band paired with 1805 – 1880 MHz?***

Yes, whole of the band.

(iv) ***Should IMT 2000 spectrum be considered as extension of 2G mobile services and be treated in the same manner as 2G or should it be considered separately and provided to operators only for providing IMT 2000 services?***

IMT-2000 spectrum must be considered as an extension of 2G mobile services and must necessarily be treated in the same manner as 2G. There is nothing exclusive about the IMT-2000 spectrum or services. 3G services are capable of being provided in various bands as has been recognized by ITU and it is for these reasons that ITU has identified additional bands for 3G services. ITU has explicitly stated that different administrations have allocated different bands for different services and hence for IMT-2000 applications also ITU has identified different bands. There is no specific IMT-2000 band reserved for 3G services all bands globally identified for IMT-2000 have equal status. Depending on the country any band including all existing bands where 2G services are available, IMT-2000 can be provided.

Under Unified Licensing Regime, which is technology and service neutral, service providers are permitted to provide all types of services and the licences do not define whether the service being provided is 2G or 3G, nor does the licence provide which technology should be used. Therefore, there is no justification that spectrum in the IMT-2000 bands be considered separately for provisioning of only IMT-2000 services as these services are in no manner different from what is possible in other bands identified by ITU.

(v) ***Reorganisation of spot frequencies allotted to various service providers so as to ensure the availability of contiguous frequency band is desirable feature for efficient utilisation of spectrum. Please suggest the ways and means to achieve it?***

Reorganisation of spot frequencies allotted to various service providers will bring about efficient utilization as one operator will have a contiguous band mitigating the need for guard bands which results in wastages.

Therefore, while reorganization is desirable for efficient utilization of spectrum, the following actions are necessary:

Setting up of a task force involving industry representatives to prepare and implement a time-bound action plan for:

- o Vacating of spectrum by non telecom service providers.
- o Harmonization of carrier assignments (especially for CDMA) which are currently in non-standardised channeling plans.

(vi) ***Whether the band 1880 – 1900 MHz be made technology neutral for all BSOs / CMSPs / UASLs and be made available with the pair 1970 – 1990 MHz or should it be kept technology neutral but reserved for TDD operations only?***

Pairing of 1880-1900 MHz band should be with 1960-1980 MHz and not 1970-1990 MHz (it is presumed that this is a typographical error).

Making the band 1880-1900 MHz technology neutral would be in sync with the Government's overall technology and service neutral approach.

One of our members HFCL Infotel Ltd., has a different view on this question.

Chapter 3: Technical efficiency of spectrum utilization

(vii) ***Please offer your comments on the methodology outlined in this Chapter for determining the efficient utilisation of spectrum. Also provide your comments, if any, on the assumptions made?***

Comments on the methodology:

In para 3.2.2 of the Consultation Paper, the terminology relates to GSM network only. Such as Broadcast Control Channel in GSM network corresponds to pilot channel for CDMA.

A few comments on assumptions:

1. The calculation on the minimum spectrum requirement for hierarchical networks in GSM (refer Para 3.2.2.3) uses a different set of assumptions than those used to estimate spectral efficiency specially in the frequency reuse factors of the macro and micro cell layers. It would better if all assumptions were consistent.

2. Regarding Efficiency Factor computed for CDMA: The assumed capacity of 25 Erlangs/Carrier/Sector will decrease as the packing density increases. It is estimated that the Erlang capacity per sector could decrease as much as a factor of 2 when the packing density reaches 5 cells/sqkm. As intercell interference stops decreasing as a 4^{th} power of distance, and starts decreasing as a 2^{nd} power of distance (i.e. as in free space loss.)

All of the above mentioned points highlight the point that technology neutrality is an important consideration in allocating spectrum. To be considered technology-neutral, the regulatory agency must come out with recommendations and incentives that supports technology and services neutral approach.

(viii) ***Please provide your perception of the likely use of data services on cellular mobile systems and its likely impact on the required spectrum including the timeframe when such requirements would develop?***

AUSPI considers rollout of data services in wireless medium easier than in wireline. It is expected that data services on mobile systems will see an exponential growth in the coming years as has been observed in South Korean example. There is a significant revenue growth in this market due to provision of data services. Popular wireless data content and applications available on CDMA networks in Korea include video messaging, video (news/TV) on demand, recording and sending of video clips, multi-media messaging, broadband Internet access, interactive gaming, live music downloads (songs and videos), etc. Wireless data services can also be used in a number of other applications such as the provision of emergency services, ATM connectivity, and Internet access in a variety of places.

We also believe that expansion of data services will result in creation of a substantial number of jobs. Also we believe that the availability of the content in regional languages will boost the usage of data services in rural areas.

AUSPI considers a requirement of 2x5 MHz spectrum / operator for data services as adequate, and this allocation should be made available immediately.

Chapter 4: Spectrum Pricing

(ix) ***Is there a necessity to change from the existing revenue share method for determining the annual spectrum charge?***

Yes, there is a necessity to change.

(x) ***If yes, what methodology should be used to determine spectrum pricing for existing and new operators? (Please refer table in Section 4.8)?***

AUSPI proposes the methodology as per the following table to determine spectrum pricing for existing and new operators:

Table: Spectrum Pricing

	New Entrants	**Spectrum to Existing Operators upto 2x15 MHz**	**Additional allocation to all existing operators beyond 2x15 MHz**
One-time Entry Fee	Same charge as the existing licensees have paid to ensure Level Playing Field	NIL	NIL
Annual Charges	Cost recovery for all spectrum*	Cost recovery for all spectrum*	AIP

***Cost recovery based on actual costs incurred by the regulatory authority in connection with management of radio spectrum.

(xi) ***In the event AIP is adopted as a means to price spectrum, would it be fair to choose GSM as a reference for determining the spectrum price?***

The value of the spectrum should be based on the "second best" technology, since this provides users of that technology with an incentive to use it in the most effective and efficient manner whilst avoiding panelizing users of the efficient technology.

(xii) ***Please provide your comments on the assumptions used in A.I.P.?***

We agree to the assumptions used in A.I.P. In addition, we recommend cell density per sq km to be also considered.

(xiii) ***In case Auction methodology is used for pricing the spectrum, please give suggestions to ensure that spectrum pricing does not become very high and spectrum is available to those who need it?***

We do not recommend auctions as the methodology for pricing spectrum.

(xiv) ***Should the new pricing methodology, if adopted, be applicable for the entire spectrum or should we continue with revenue share mechanism till 10 + 10 MHz, and apply the new method only for spectrum beyond this?***

We do not consider the revenue sharing as appropriate and accordingly recommend discontinuance of revenue sharing mechanism.

The price mechanism should be as follows:

- Upto 15+15 MHz spectrum – cost recovery based on actual costs incurred by the regulatory authority in connection with management of radio spectrum.

- Beyond 15+15 MHz spectrum based on A.I.P.

In this connection please refer to our response to question (X).

(xv) ***What incentives be introduced through pricing to encourage rural coverage and / or using alternative frequency bands like 450 MHz?***

Spectrum charges should be totally waived for wireless coverage in rural / remote areas and / or for using alternative frequency bands like 450 MHz. This will help in reducing costs of provisioning of service in these areas where revenue generated is far below the costs. This will come as a big relief to operators to provide services in rural areas also.

(xvi) ***Does M X C X W formulae for fixed wireless spectrum pricing need a revision? If so, suggest the values for M, C, W?***

Yes for UASLs. We recommend that fixed wireless spectrum pricing be revised and should be the same as is adopted for GSM cellular operators now.

The present rate of 0.25% of AGR for bandwidth of 112 MHz for the Circle and 224 MHz for the Metro may be retained. Additional spectrum of 28 MHz for the Circle and 56 MHz for the Metro may be charged at 0.05% of AGR.
In view of this, the formulae M X C X W is no longer valid.

This should be effective from date of migration of BSOs to UASL.

We would like to bring the following facts regarding disparity in frequency spots allocation with our views:

UASLs who apply for microwave links are allocated frequency spots on town-wise basis for a particular circle whereas CMSPs are allocated the frequency spot for the entire circle and need not take permissions for each and every town where service is being commissioned. In the light of migration to UASL regime, UASLs should also be allocated frequency spots for the entire circle as is being given to CMSPs instead of town-wise allocations. This will reduce and simplify the procedures and UASLs would not have to file applications for various towns as they rollout their network but would get one allocation for the entire circle.

(xvii) ***Should there be different pricing levels for shared spectrum versus spectrum that is allocated with protection? How should this be determined?***

The entry fee paid by the operator allows the licensee the right to use the spectrum which is protected under the license. Additionally, each licensee pays annual license fee charges for usage of this spectrum through a revenue share. Therefore, no further increased / higher charges are payable for this “protected” spectrum by licensed service providers.

However, for shared spectrum, this should be charged in proportion to the number of users.

Chapter 5: Spectrum allocation

(xviii) ***How much minimum spectrum (refer approach (I) and (II)) in section 5.4) should each existing operator be provided? Give the basis for your comments?***

In a price sensitive, highly competitive market like India's, there is substantial change in traffic as tariffs vary and therefore, this upsets the basic assumption of constant traffic pattern. This phenomenon is likely to continue as we can expect a higher uptake of mobile services in the years to come. Thus, networks in India have to be robust and designed and planned in such a manner that these fluctuations are factored into without affecting the quality of service. Operators would have to do a techno-economical trade-off between adding infrastructure say in a particular metro area as compared to another urban centre vis-à-vis getting additional allocation of spectrum.

Keeping all these factors and international practices in mind, it is better in the Indian context that the Government allows each CDMA operator an average of 2x15 MHz allocations immediately in internationally accepted bands viz. 800 and US PCS 1900 MHz bands as suggested in Approach II outlined in the Consultation Paper. This would allow operators to plan efficient and reliable network keeping the overall network cost down. This approach is far more suitable to ensure the growth and viability of market place here.

We do not recommend Approach I. This Approach I has very serious flaws including that it is not technology neutral as required in Unified Licensing Regime.

However, as it has been noted by TRAI in the Consultation Paper, while there is some additional frequency available after this allocation (2x10 MHz / operator) for GSM in the 900 and 1800 MHz bands, there is actually a deficit of 2x10 MHz in non-metro areas which goes upto 2x20 MHz in metro areas for CDMA. While earmarking these bands, it is imperative to appreciate that current availability of equipment in the proposed bands alongwith their compatibility with existing 800 MHz systems (infrastructure and handsets) already deployed is a pre-requisite so that operators can benefit from the economies of scale. With this background, we feel that additional allocations for CDMA services be made in the US PCS band (1850-1910 MHz paired with 1930-1990 MHz).

(xix) ***At what stage the amount of spectrum allocation to new entrants be considered in the 800 MHz / 900 MHz / 1800 MHz frequency bands?***

Presently, there are about 7-8 licensed and / or operational networks in each service area (Metros / Category A & B circles) and similarly about 5-6 networks in Category C circles. This fact exhibits the high level of competition across the country. The Government should allocate on an average of 2x15 MHz / operator irrespective of circle and technology opted for by the operator. For new entrants, allocations should be made only after the existing operators have been allocated an average of 2x15 MHz of spectrum.

(xx) ***Should spectrum be allocated in a service and technology neutral manner?***

While considering India specific spectrum related issues, it has to borne in mind that the Government of India has adopted technology neutral approach and has issued Unified Access Licenses under which licensees can provide any kind of services, spectrum too should be allocated in a service and technology neutral manner. That is, a licensed service provider will be totally free to use any technology to provide any kind of service without any regulatory restrictions.

(xxi) ***What should be the amount of cap on the spectrum assigned to each operator?***

The amount of cap per operator should be on an average of 2x20 MHz of spectrum and it should be reviewed from time to time as and when required.

(xxii) ***What procedure for spectrum allocation be adopted for areas where there is no scarcity and in areas where there is scarcity?***

India, being a divergent country with varying income levels and socio-economic patterns presents a complex market where no "straight-jacket" / "one size fits all" solution can emerge. We feel that in areas where there is no scarcity today, spectrum may be allocated on demand.

(xxiii) ***Which competitive spectrum allocation procedure (Auction / Beauty Contest) be adopted in cases where there are scarcity?***

For competitive allocation procedure, AUSPI strongly proposes that no auctions should be there for allocation of spectrum.

2x15 MHz spectrum must be allocated and priced as cost recovery based on actual costs incurred in connection with management of radio spectrum.

After the allocation of 2x15 MHz / operator, we recommend the adoption of AIP as enumerated in our response to Chapter 4 of the Consultation Paper to price the spectrum.

(xxiv) ***Should we consider giving some spectrum in 900 MHz band to fourth CMSPs?***

The telecom landscape in India is witnessing dramatic change with the announcement of mergers and acquisitions. Under the M & A Guidelines announced by the Government, spectrum caps have been instituted on merged entities. While this restructuring continues, the Government should ensure that 900 MHz band which is currently being utilized by the 1st, 2nd and 3rd Operators is freed up by 5 MHz (890-894 MHz) and GSM operators are accommodated in the 1800 MHz band to allow for usage by CDMA as per the international practice so that the 25+25 MHz can be fully utilized by CDMA operators. CDMA operators are short of 5 MHz of spectrum in the 800 MHz band and this harmonization will make up for some of this shortfall for the CDMA operators. This will allow for effective utilization of 5 MHz (845-849 MHz) which is presently being wasted and cannot be used due to GSM occupying its corresponding band (890-894 MHz).

(xxv) ***Comments of stakeholders are invited on the minimum blocks such as 2 X 2.5 MHz / 2 X 5 MHz of additional spectrum to be allocated to existing service providers in situations where IMT 2000 band is opened as well as in situation where it is not opened. Additionally, comments are also invited on the minimum allocation to new entrants?***

Unified Licensing Regime is technology and service neutral, AUSPI therefore proposes that additional spectrum for existing operators be allocated in minimum blocks of 2x5 MHz / operator. International practice supports the allocation of blocks of 5, 10 and 15 MHz of spectrum.

As regards allocation to new entrants, we propose that after meeting the requirements of existing operators, allocation of spectrum to new entrants be considered.

(xxvi) ***In the event that IMT 2000 spectrum is treated as continuum to 2G, should existing operators using spectrum below the specified benchmark be treated as those eligible for IMT 2000 spectrum?***

Yes

Chapter 6: Re-farming, Surrender, Spectrum trading and M&A

Re-farming:

(xxvii) ***What approach should be adopted to expedite the re-farming of 1800 MHz and IMT-2000 spectrum from existing users?***

The Government funding should be the approach for the re-farming of the existing users whether Government or private sector. Government can fund this out from the revenue earned from entry fee, spectrum fee, etc. to anyone.

(xxviii) ***What approach should be adopted for re-farming of spectrum after expiry of license?***

AUSPI's view is that this is a hypothetical question. There will be active customers even after the expiry of the license.

Surrender of spectrum:

(xxix) ***Should there be any refund for spectrum surrender in principle?***

Today there is no excess spectrum with CDMA service providers to surrender. However, it is felt that in case of forced surrender of spectrum by any operator, there should be a refund.

(xxx) ***Should there be refund for spectrum surrender consequent to Unified Access license policy? If yes, what should be the basis?***

No, for the reasons as follows:-

(a) Refund of spectrum is an operator's internal decision and so no compensation is due;
(b) While the operator was given the spectrum, his competitors were denied the same and accordingly a refund would mean a revenue loss to the Government and denial of services to users.
(c) It is very difficult to bifurcate the amount of entry fees paid at that time between spectrum and service.
(d) Also, the operator has already used the spectrum for a number of years.

(xxxi) ***How should the amount of refund be estimated?***

Not applicable

Spectrum trading:

(xxxii) ***Should we open up the spectrum market for spectrum trading? If yes, what should be the time frame for doing so?***

&

(xxxiii) ***What are the pre-requisites to adopting spectrum trading?***

AUSPI feels that opening of trading of spectrum requires lot of technical and legal preparedness and in any case is not relevant now. It may be considered at a later stage.

Mergers & Acquisitions:

(xxxiv) ***Whether we should specify a cap higher than 2 X 15 MHz for Metros and Category "A" service area and 2 X 12.4 MHz for Category "B" and "C" service area in case of M&As or should it be retained?***

We recommend a cap of 2x20 MHz of spectrum for all service areas, i.e. Metros, Category A, B and C circles in case of mergers and acquisitions.

(xxxv) ***In case, IMT 2000 is considered as a continuum of 2G Services, is there a need to have a cap higher than that without IMT 2000 services? Should there be individual caps on 2G and 3G spectrum or a combined cap?***

We recommend a uniform cap of 2x20 MHz of spectrum per operator. In fact, there is no need to differentiate between the spectrum bands and the cap should be a combined cap.

(xxxvi) ***In case of M&As where the merged entity gets spectrum exceeding the spectrum cap, what should be the time frame in which the service provider be required to surrender the additional spectrum?***

AUSPI proposes a six months time frame as adequate to reduce the allocations to levels within the cap after which deterrent penalties be applicable so that merged entities do not gain undue advantages over their competitors.

*****

ANNEXE-I

S. No	Country	Operator	Bandwidth Per Operator
1.	Argentina	CTI Holdings GTE PCS Movicom BellSouth Moviles SA	15 MHz
2.	Australia	Hutchison Telstra	10MHz
3.	Brazil	BSI-BCP Cellular CRT Global Telecom Telemig Telebahia / Telergipe Telefonia Cellular Telesp Vesper	11.5 MHz
4.	Canada	Bell Mobility (Ontarioa) Telus Mobility	12.5 MHz
5.	Chile	BellSouth Communicaciones SmartCom	10 MHz
6.	China	China-Unicom	10MHz
7.	Dominican Republic	All America Cable & Radio Inc Codetel TRICOM	20 MHz
8.	HongKong	Hutchison	7.5MHz
9.	Indonesia	Komselindo	10MHz
10.	Japan	KDDI	15MHz
11.	Korea	SK Telecom Shinsegi Telecom	12 MHz
12.	Mexico	Baja Cellular Iusacell Pegaso PCS SPC	17.5 MHz
13.	New Zealand	Telecom NZ	20MHz
14.	Philippines	Pitel	10MHz
15.	Taiwan	Asia-Pac Broadband Wireless com (BT)	20 MHz
16.	Thailand	Tawan	12.5 MHz
17.	USA	Alltel Alpine PCS Inc BRK Wireless Co. Inc	18 MHz

		Cingular Wireless **ClearComm** **Horizon PCS** **Kansas Personal Communications**	

ANNEXE-II

Country	Operator	Date	Technology	Frequency Band
Korea	SK Telecom	Oct 1, 2000	CDMA2000	800 MHz
Korea	LG Telecom	May 1, 2000	CDMA2000	**1800 MHz (Korean PCS)**
Korea	KT Freetel	May 2, 2000	CDMA2000	**1800 MHz(Korean PCS)**
USA	Monet	Oct 21, 2000	CDMA2000	1900 MHz
Brazil	Telesp	Dec 10, 2001	CDMA2000	800 MHz
USA	Leap Wireless	Jan 17, 2002	CDMA2000	1900 MHz
USA	Verizon Wireless	Jan 28, 2002	CDMA2000	800 and 1900 MHz
USA	MetroPCS	Feb 1, 2002	CDMA2000	1900 MHz
Canada	Bell Mobility	Feb 12, 2002	CDMA2000	800 and 1900 MHz
Japan	KDDI	Apr 1, 2002	CDMA2000	800 MHz
Puerto Rico	Centennial Wireless	Apr 4, 2002	CDMA2000	1900 MHz
Brazil	Telefonica Cellular	Apr 16, 2002	CDMA2000	800 MHz
Canada	Telus Mobility	June 3, 2002	CDMA2000	800 and 1900 MHz
New Zealand	Telecom N.Z.	July 22, 2002	CDMA2000	800 MHz
Chile	Smartcom PCS	July 26, 2002	CDMA2000	1900 MHz
USA	Sprint PCS	Aug 8, 2002	CDMA2000	1900 MHz
USA	Cellular South	Sept 9, 2002	CDMA2000	800 MHz
Moldova	Interdnestrcom	Sept 30, 2002	CDMA2000	800 MHz
Israel	Pele-Phone	Oct 1, 2002	CDMA2000	800 MHz
Colombia	EPM-Bogota	Oct 2, 2002	CDMA2000	1900 MHZ
India	TataTeleservices	Nov 7, 2002	CDMA2000	800 MHz
Venezuela	Telcel	Nov 13, 2002	CDMA2000	800 MHz
USA	KiwiPCS (Comscape)	Nov 14, 2002	CDMA2000	1900 MHz
Venezuela	Movilnet	Nov 20,	CDMA2000	800 MHz

		2002		
Canada	Aliant Mobility	Nov 25, 2002	CDMA2000	800 MHz
Canada	MTS Mobility	Nov 27, 2002	CDMA2000	1900 MHz
Indonesia	Telecom Flexi	Dec 1, 2002	CDMA2000	800 MHz
Australia	Telstra	Dec 1, 2002	CDMA2000	800 MHz
Ecuador	Bell South	Dec 3, 2002	CDMA2000	800 MHz
Panama	Bell South	Dec 3, 2002	CDMA2000	800 MHz
Mexico	IUSACELL	Jan 24, 2003	CDMA2000	1900 MHz
Puerto Rico	Verizon Wireless	Feb 4, 2003	CDMA2000	800 MHz
Thailand	Hutchison CAT	Feb 27, 2003	CDMA2000	800 MHz
Nicaragua	Bell South	Mar 26, 2003	CDMA2000	800 MHz
Dominican Republic	Centennial Dominicana	Mar 27, 2003	CDMA2000	1900 MHz
China	China Unicom	Mar 28, 2003	CDMA2000	1900 MHz
Canada	Sasktel Mobility	Apr 10, 2003	CDMA2000	800 MHz
Columbia	Bell South	Apr 15, 2003	CDMA2000	800 MHz
Brazil	Giro (Vesper)	May 01, 2003	CDMA2000	1900 MHz
India	Reliance Infocomm	May 01, 2003	CDMA2000	800 MHz
India	Garuda 1X	May 19, 2003	CDMA2000	800 MHz
Guatemala	Bell South	May 20, 2003	CDMA2000	1900 MHz
USA	Midwest Wireless	June 16, 2003	CDMA2000	1900 MHz
Vietnam	S-Fone	July 01, 2003	CDMA2000	800 MHz

Guatemala	PCS	July 15, 2003	CDMA2000	1900 MHz
Taiwan	APBW	July 29, 2003	CDMA2000	800 MHz
Chile	BellSouth	Aug 11, 2003	CDMA2000	1900 MHz
Peru	Telefonica Moviles	Dec 1, 2003	CDMA2000	800 MHz