Revised spectrum forecasts using the new spectrum model

Spectrum required for various mobile communications markets in 2020

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Content

Exhibits

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1. Introduction

1.1 Background

In 2012, a new model for spectrum estimation was commissioned by the GSM Association to estimate future spectrum requirements for different countries and mobile markets and provide an input into the ITU long term spectrum requirement planning process.

Rather than taking a theoretical approach, the starting point of the model is the existing number of base station sites within a given market and scope for future site densification. A transparent methodology based on established planning parameters is used to estimate the future spectrum that will be needed to support the forecast traffic.

A description of the model and preliminary results for four countries were submitted to the ITU in September 2012. These demonstrated the value of the approach but it was recognised that further discussion and refinement of the input parameters were required.

Since then, further research has been undertaken to validate the radio planning assumptions used in the model. These parameters set the balance between network quality and spectrum required. Some changes were considered appropriate, with the result that spectrum estimates in this report are slightly increased. In addition, we have attempted to develop more accurate site estimates for the four countries considered.

1.2 Scope

This report briefly describes the main parameters that drive the spectrum forecast and changes made since the last report are highlighted. A more detailed description of the model can be found in the earlier report[1] and justification of specific planning parameters is set out in Appendices A and B.

Revised spectrum forecasts for the UK, Brazil, China and the USA are presented in Section 3. Where existing site numbers have been revised the basis for the new assumptions are explained.

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[1] A new model for spectrum estimation, Report for GSMA, 25 Sept 2012, Coleago Consulting

2. Overview of model and key parameters

2.1 Overview

The earlier report describes the problems that mobile operators face in supporting increasing levels of mobile data traffic. Improvements in technology and spectrum efficiency can help but the issue ultimately comes down to the number of base station sites that an operator is able to install and the available spectrum.

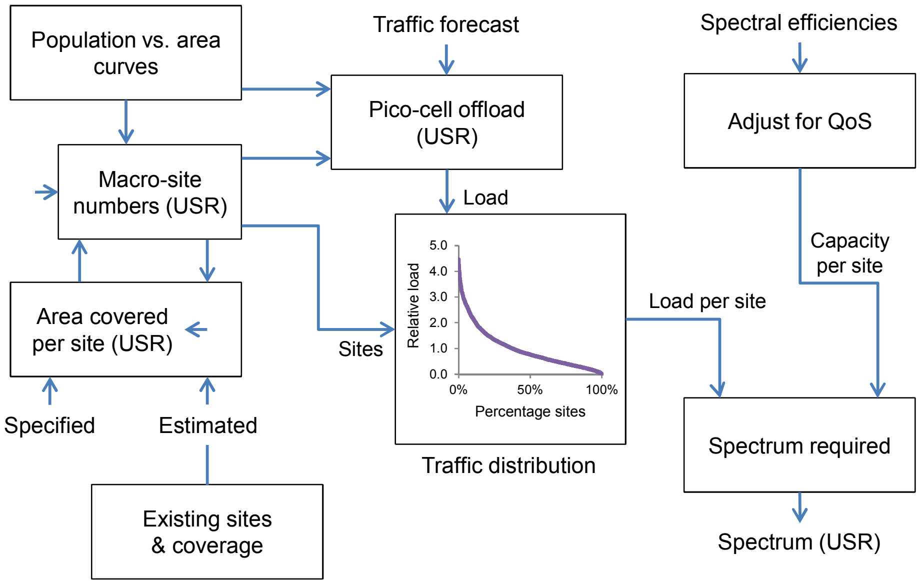
The new spectrum model estimates the future spectrum requirement for a given number of cell sites and presents the relationship between numbers of cell sites and spectrum required for a given network load. It has been designed so that it can be readily applied to different countries and markets around the world.

At a high level, spectrum requirement is determined by considering:

- The existing number of base station sites within a given market and the scope for future site densification. This can be difficult to establish, as discussed in relation to the four countries modelled below.
- Spectrum efficiency. The capacity of each site is determined by basic spectral efficiency for the technology, the number of sectors per site, signalling overhead and a quality margin that will ensure good quality and low delay.
- The traffic load per site. The model accepts voice and data traffic forecasts in various formats. Cisco regional forecasts of monthly usage have been used for these forecasts and are converted to busy hour Mbps for the most congested cell sites.

A block diagram showing the main steps in the analysis is shown in Exhibit 1. For a more detailed description see the earlier report (Footnote 1 above).

Exhibit 1: Functional block diagram



Source: Coleago Consulting Ltd

2.2 Key parameters

The model allows information to be input in a number of different ways but the basic calculation is straightforward and given by:

$$S = (T/N \times M) \div C$$

Where: $S =$ Spectrum (MHz)

$T =$ Total traffic (Mbps)

$N =$ Number of macro-cell sites

$M =$ Load multiplier for highly congested sites

$C =$ Capacity of site (Mbps/MHz)

The key parts of this equation are discussed further below.

2.2.1 Number of cell sites

The number of cell sites (*N*) at the end of the plan is given by the number of existing sites and assumed rates of site densification. Sites are split between urban, suburban and rural areas.

2.2.2 Traffic

The model currently takes forecasts of regional monthly mobile data traffic (in millions of GB) from Cisco and monthly voice minutes of usage from Wireless Intelligence. These are converted to average busy hour site traffic (*T*) assuming:

- 15% of the daily data traffic occurs in the average site data busy hour
- 8.5% of the daily voice traffic occurs in the average site data busy hour
- Voice is converted to data at an equivalent rate of 21 kbps.

The busy hour percentages relate to the cell or site busy hour which is peakier than the network busy hour traffic. Network congestion is determined by the busiest sites rather than the average site. A typical site busy hour traffic distribution profile is shown in Exhibit 2 where the distribution is relative to the average site busy hour traffic. This provides the load multiplier (*M*) for the most congested sites, in this case the top 2% sites.

It should be noted that the 15% busy hour percentage of daily traffic is higher than the 12% figure used for the preliminary results, for sound the reasons discussed in Appendix A. The impact of this change is to raise the spectrum forecast by 25%. Other parameters remain unchanged.

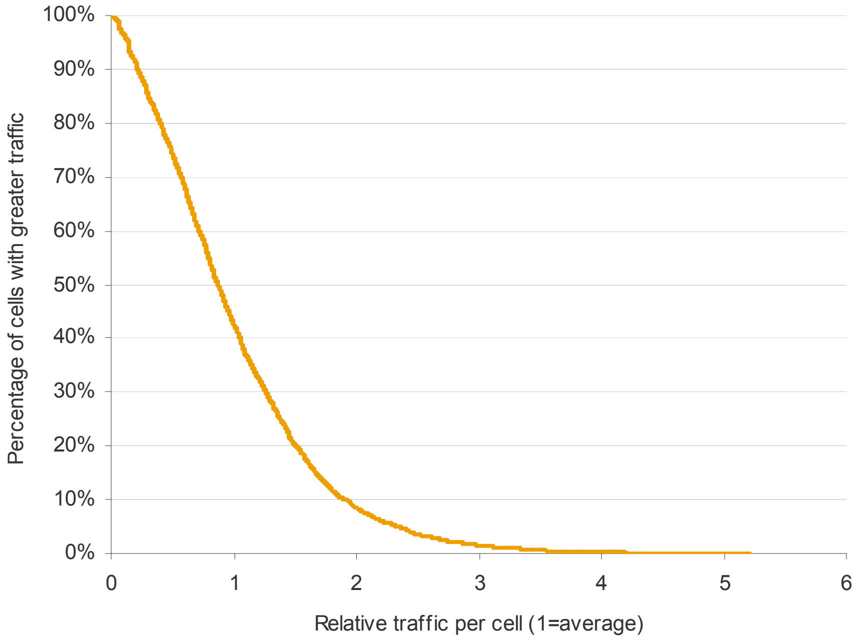
2.2.3 Site capacity

Site capacity in Mbps/MHz is obtained by multiplying spectrum efficiencies in urban, suburban and rural environments by the average sectors per site. The resulting site capacities relate to Layer 1 (physical layer), whereas the combined voice and data traffic (*T*) relates to the Layer 3 (user level). In order to convert the busy hour traffic (*T*) to an appropriate Layer 1 figure, it is necessary to:

- Add a signalling overhead (15%)
- Apply a quality of service factor (50%) to ensure services can be supported with high quality and low delay.

These values have not changed since developing the preliminary results. However, further validation of these parameters has been carried out as described in Appendix B.

Exhibit 2: A typical distribution of site BH traffic for a mobile network



Source: Coleago Consulting Ltd

3. Results

3.1 Country specific inputs

As described in the earlier report (Footnote 1 above), the model requires the following country-specific data for each country of interest:

- Mobile data and voice traffic forecasts covering the period to 2020 supplied by CISCO and Wireless Intelligence respectively to drive the spectrum demand
- Population distribution data available from SEDAC, which is used to area versus population coverage curves and to break the country into urban, suburban and rural areas
- Estimate of existing site numbers and densification over the period. These are critical in establishing a reliable spectrum estimate.

Experience has shown that it is not easy to obtain reliable or definitive estimates of site numbers. We require the number of macro-cell sites available to a single operator for national coverage, with the assumption that the total spectrum may be deployed at each site.

In order to model urban, suburban and rural areas accurately, the breakdown of sites and traffic between these areas is also required. This level of detail was not available for the current estimates. In fact in practice, available information is often incomplete and almost invariably ambiguous. Interpolation and interpretation of different sources are required.

3.2 Revised spectrum forecasts

New information received since the preliminary results were prepared has resulted in some changes being made to estimated site numbers for Brazil, China and the USA, as documented below.

3.2.1 The UK

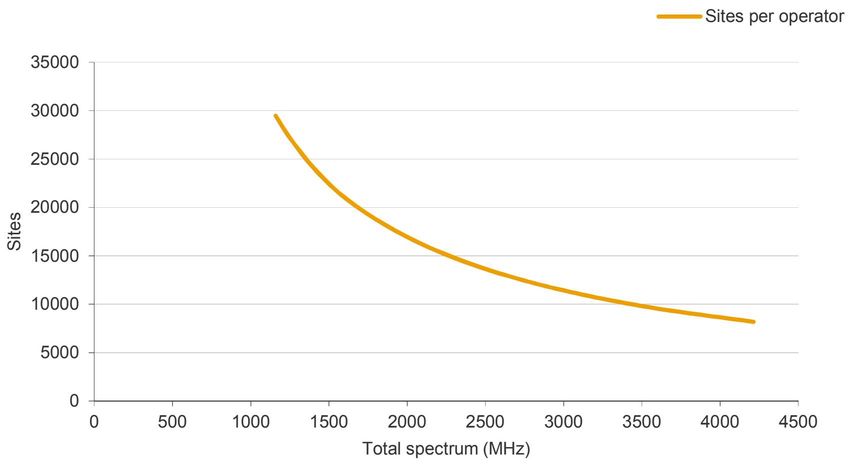
Revised results for the UK indicate a total spectrum of 2074 MHz will be required in 2020, assuming the number of macro-sites per operator to be 16,370.

The increase in spectrum since the previous estimate arises from the attribution of a higher level of daily data traffic to the site busy hour as discussed in Section 2.2.2 and Appendix A.

The increase in the total number of sites is due to the assumption of slightly higher densification rates in rural and suburban areas, although urban areas remain unchanged.

A graph of sites per operator versus total spectrum requirement is presented below:

Exhibit 3: UK sites per operator versus total spectrum in 2020



Source: Coleago

3.2.2 Brazil

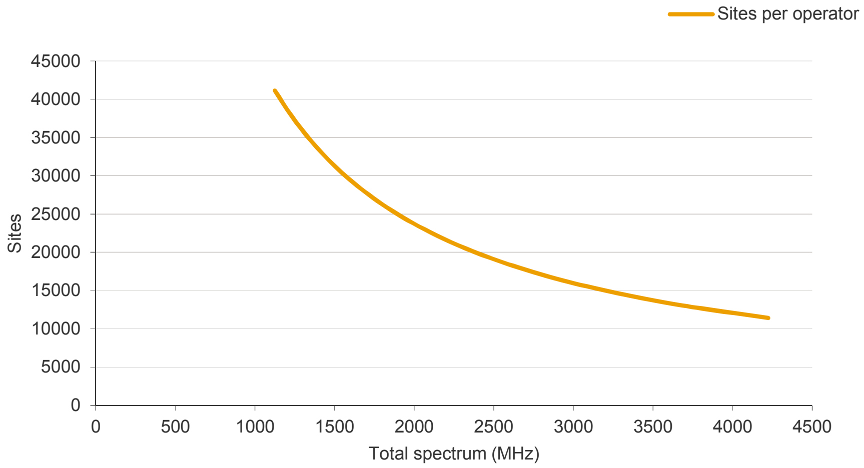
Revised results for Brazil indicate a total spectrum of 2080 MHz will be required in 2020 assuming to a total of 22,850 macro-sites per operator.

The increase in spectrum since the previous estimate arises from the attribution of a higher level of daily traffic to the site busy hour as discussed in Section 2.2.2 and Appendix A.

Initial site numbers have increased slightly following an analysis of data on the Brazilian Regulator, Anatel's website. At the same time, rates of densification in urban areas have been lowered, bringing the figure more in line with developed countries.

A graph of sites per operator versus total spectrum requirement is presented below.

Exhibit 4: Brazil sites per operator versus total spectrum in 2020



Source: Coleago

3.2.3 China

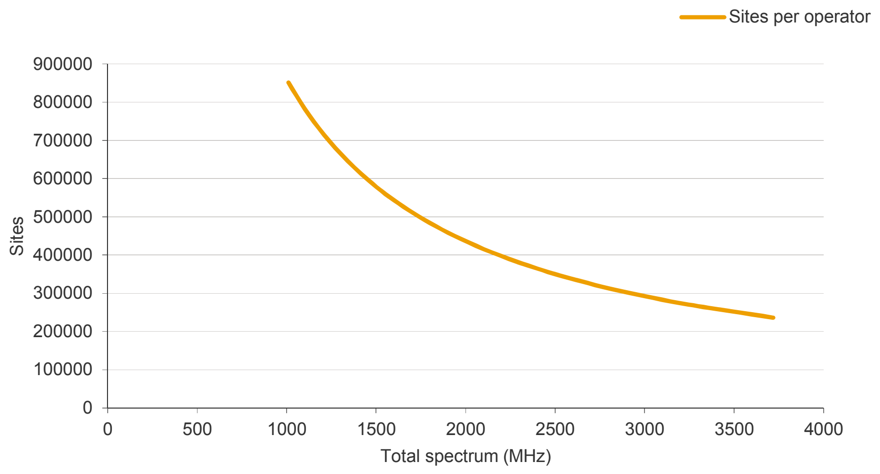
Revised results for China indicate a total spectrum of 1844 MHz will be required in 2020 assuming a total of about 472,900 macro-sites per operator.

The result has changed little from the preliminary estimate, since the attribution of a higher level of daily traffic to the site busy hour is largely offset by an increase in site numbers.

Current site numbers were obtained from Chinese operators, involving some further assumptions. Rates of densification have been adjusted to give different values in urban, suburban and rural areas.

A graph of sites per operator versus total spectrum requirement is presented below.

Exhibit 5: China sites per operator versus total spectrum in 2020



Source: Coleago

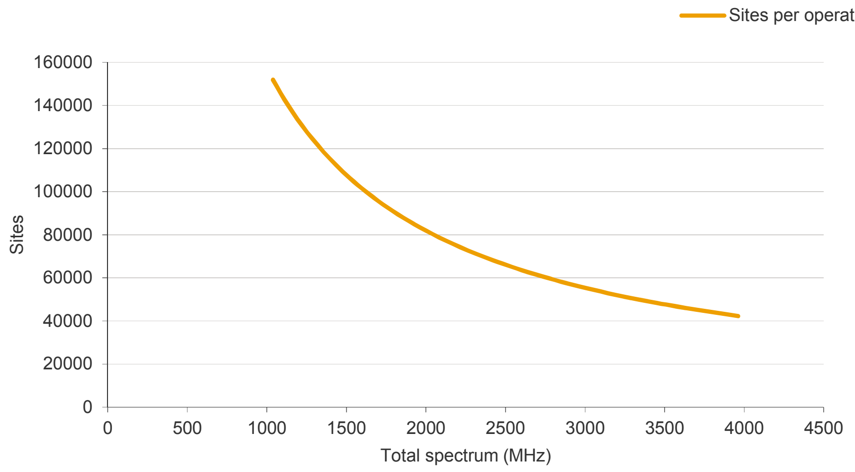
3.2.4 USA

Revised results for the USA indicate a total spectrum of 1939 MHz will be required in 2020 assuming a total of about 84,420 macro-sites for a national operator.

Overall site numbers have increased following a more detailed analysis of an earlier spectrum paper submitted to the ITU by the USA. This has resulted in a higher number of sites per operator for 2012. Overall rates of site densification are in line with trends identified in the USA, with lower rates in urban areas, in line with other developed countries.

A graph of sites per operator versus total spectrum requirement is presented below.

Exhibit 6: USA sites per operator versus total spectrum in 2020



Source: Coleago

3.3 Urban, suburban and rural differences

The question is sometimes asked whether the spectrum model could inform the requirement for low band versus high band spectrum.

Low band spectrum is required for rural coverage but is also needed for providing reliable indoor coverage in urban and suburban areas. While recognising this limitation, the model can provide separate estimates for urban, suburban and rural area, setting a lower bound on the low-band spectrum required. However, sufficiently detailed information was not available when producing the current spectrum forecasts.

4. Conclusions

Since the preliminary results were produced in September 2012, there has been further validation of the model assumptions and parameters. This has resulted in minor changes and provides confidence in the validity of the results.

The results point to about 2 GHz total spectrum being required assuming appropriate asymmetric allocations.

Further work could be undertaken to investigate the different amounts of spectrum required in urban, suburban and rural areas. However, more detailed input data will need to be supplied and carefully considered. At the same time pico-cell offload, which remains unchanged since the previous report could be refined.

Appendices

Appendix A: **Estimating the traffic load**

The model estimates spectrum by dividing the busy hour load per site in Mbps by the site capacity, in Mbps per MHz. Spectrum efficiencies within the model are quoted in bps/Hz (or Mbps/MHz) and apply to Layer 1, the physical layer.

Traffic forecasts supplied by Cisco are annual or monthly forecasts in millions GB and relate to the user level, Layer 3. These forecasts need to be converted to busy hour site load for the busiest sites. The steps are as follows:

- **Conversion of monthly traffic to daily traffic volume (÷30)**
- **Conversion to average site busy hour traffic volume (15%)**
  Site level busy hour traffic is peakier than network busy hour, where the busy hour traffic may be typically 8%. It is recognised that individual sites may have busy hour traffic in the range of 10% to 20% or even higher. An average value of 15% is appropriate as shown by Holma and Toskala in their text book on LTE for UMTS. [2]
- **Derivation of load for busiest sites**
  A curve as shown in Exhibit 2 is used to estimate the cell load for the busiest sites based on the average site load. The curve is obtained from an analysis of site busy hour traffic statistics from a network OMC. Analysis of different networks shows this curve to be remarkably similar across operators and markets.
- **Add signalling overhead to obtain Layer 1 traffic load (15%)**
  The ratio of Layer 3 to Layer 1 traffic is typically 87% for LTE (82% for HSPA). Taking the LTE figure corresponds to a 15% (1/0.87) signalling overhead.

Finally the traffic load is converted from total GB to Mbps throughput.

Appendix B: **Spectral efficiencies and Quality of Service**

The model assumes spectrum efficiencies ranging from 0.3 bps/Hz in 2012 to 1.96 bps/Hz in 2020. These figures should be representative of Layer 1 carrier throughput performance in macro-cell environments. They do not represent peak rates or apply to pico-cells which will experience higher spectrum efficiencies.

The spectrum efficiency figure time the available spectrum provides a maximum Layer 1 throughput per cell but a network built on this basis would not provide a good quality service. Typically operators design to 50% to 70% of this loading and the preliminary results were developed using a 50% quality of service factor.

Further work has been undertaken to validate this figure. A white paper by Nokia Siemens Networks[3] states 'A margin in the busy hour needs to be reserved in order to guarantee low delays and reasonably good data rates' and suggests a maximum 50% loading. The impact on LTE 20 MHz would be to lower the design throughput to 17.5 Mbps or 0.875 bps/Hz.

Similarly, recent work undertaken by Telstra, Australia shows that network throughput and performance should be modelled on the basis of a 'File Transfer Protocol' traffic model rather than a 'Full buffer' traffic model usually employed. The result is equivalent to designing for a 50%-70% load. Simulations show typical effective spectrum efficiencies just below 1 bps/Hz.

These results are consistent with the values used in the spectrum model and it was therefore decided to maintain the quality design factor at 50%.

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[2] Figures 9.37 and 9.38., LTE for UMTS: Evolution to LTE-Advanced, 2nd Edition, Holma and Toskala, ISBN: 978-0-470-66000-3, Figures 9.37 and 9.38.

[3] Mobile Broadband with HSPA and LTE – capacity and cost aspects, While Paper, Nokia Siemens Networks, April 2011