

**UMTS Forum Report No. 40**

**Development of spectrum  
requirement forecasts for IMT-2000  
and systems beyond IMT-2000  
(IMT-Advanced)**



**January 2006**

## **UMTS Forum Report No. 40: Development of spectrum requirement forecasts for IMT-2000 and systems beyond IMT-2000 (IMT-Advanced)**

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# 0 Executive summary

## 0.1 Introduction

This report has been prepared by Analysys Consulting Ltd. (Analysys) on behalf of the UMTS Forum to develop spectrum forecasts for IMT-2000 and systems beyond IMT-2000, to support the UMTS Forum's contribution to preparations for the World Radiocommunication Conference in 2007 (WRC-07).

The European cellular market is currently implementing UMTS networks and services. Beyond this, the industry is already looking ahead towards the future (the systems beyond IMT-2000<sup>1</sup>). One of the key questions for cellular operators and regulators alike is what will be the spectrum requirements for these services in the future?

The future spectrum requirements are highly dependent on the future demand for cellular services and the traffic they generate. The UMTS Forum and the European Commission (EC) have commissioned studies to investigate the future demand for these services and the resulting traffic generated. These studies are the *Magic mobile future 2010-2020* and *The demand for future mobile communications markets and services in Europe (FMS)* respectively, both of which were published in April 2005.

The objective of the present study is to calculate the future demand for spectrum from IMT-2000 and systems beyond IMT-2000, up until 2020, using the traffic profiles forecast in the *Magic mobile future* and *FMS* studies mentioned above. Our methodology is based on the approach used for quantifying future spectrum demand for cellular services during Analysys's recent study for the Independent Audit of Spectrum Holdings (IASH) in the UK.<sup>2</sup>

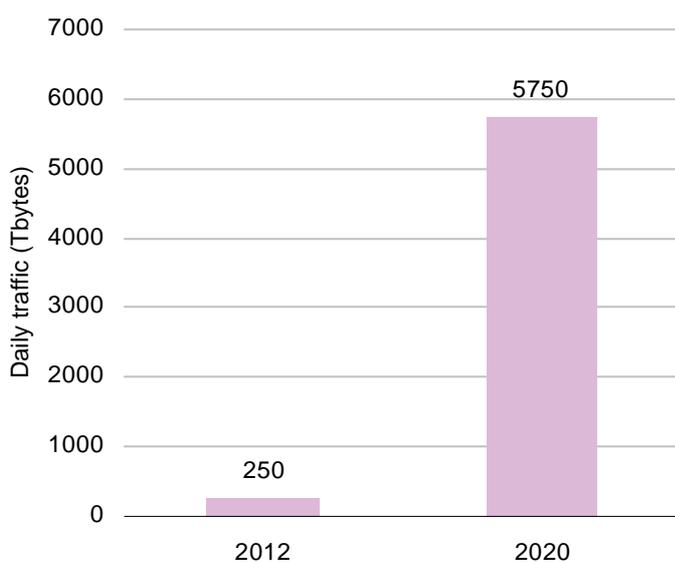
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<sup>1</sup> Also known as IMT-Advanced.

<sup>2</sup> See [www.spectrumaudit.org.uk](http://www.spectrumaudit.org.uk) or [www.analysys.com](http://www.analysys.com) for further details of this study.

## 0.2 Description of the traffic forecasts

The *Magic mobile future* study forecasts traffic for just one of the three scenarios developed in the study, namely “Scenario 2: Balanced, broad-based growth”. Exhibit 0.1 below shows the traffic forecasts for this study.



**Exhibit 0.1:**  
*Magic mobile future*  
 forecast of daily  
 traffic for a  
 representative  
 European country  
 [Source: *Magic*  
*mobile future*, 2005]

The *FMS* study contains forecasts for three scenarios: “smooth development”, “economic stagnation” and “constant change”. The majority of the 43 respondents to the study considered the “constant change” scenario as the most plausible, which was later chosen as the basis of the market input from the European Conference of Postal and Telecommunications Administrations (CEPT) to the International Telecommunications Union (ITU-R). Exhibit 0.2 contains traffic forecasts for each of these scenarios.

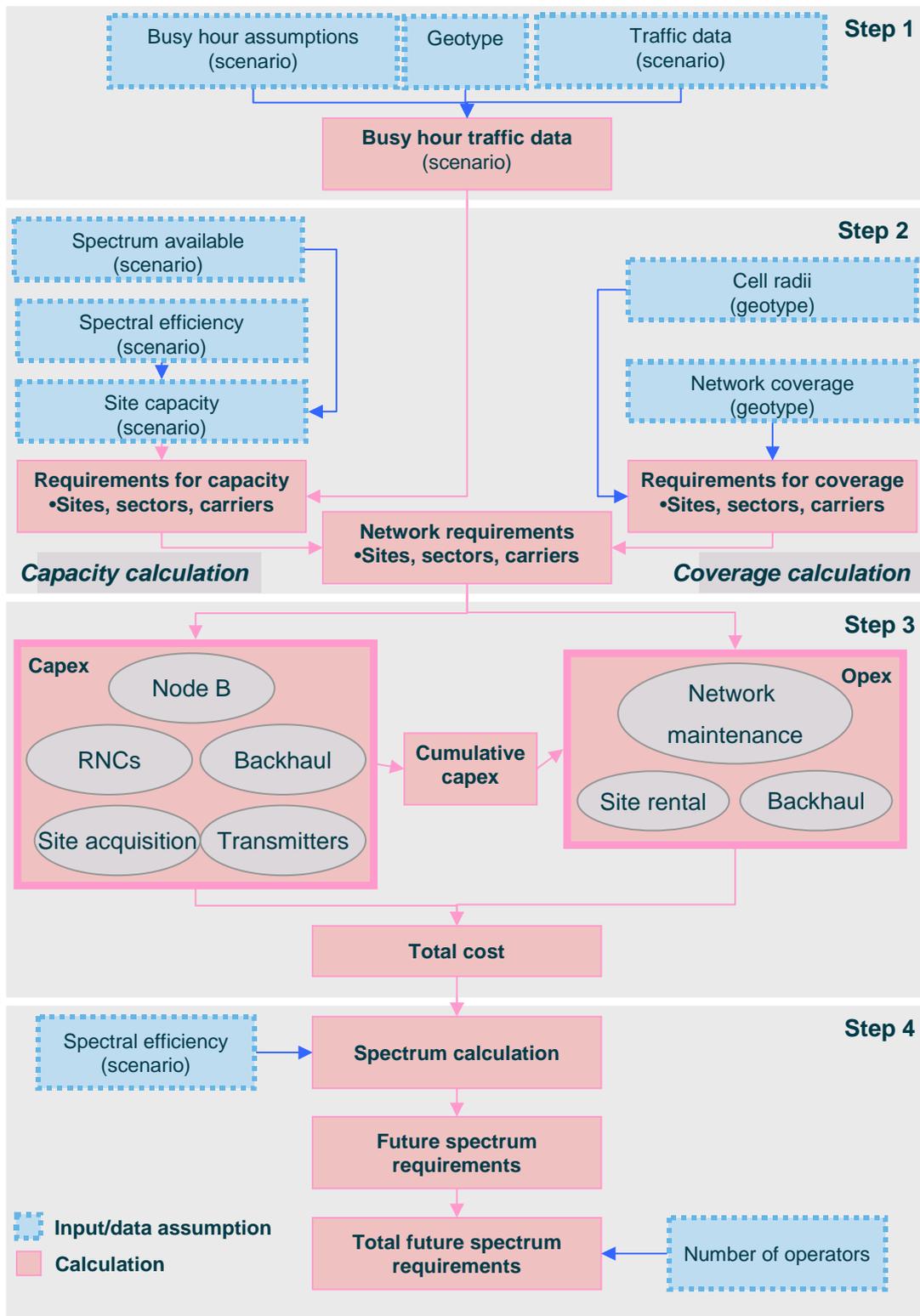
	<i>Smooth development</i> (millions of mins of 1Mbit/s)	<i>Economic stagnation</i> (millions of mins of 1Mbit/s)	<i>Constant change</i> (millions of mins of 1Mbit/s)
2010	27 400	21 236	27 554
2015	137 141	15 210	111 426
2020	918 026	56 709	332 630

**Exhibit 0.2:** *FMS traffic forecasts by scenario* [Source: *FMS*, 2005]

### **0.3 Spectrum forecast methodology**

In order to develop an understanding of how demand of cellular spectrum will evolve over the next 15 years, the study takes the perspective of a mobile network operator (MNO). In the event of traffic increasing on its network in the future, an MNO faces a trade-off between trying to obtain more spectrum and deploying more carriers, or deploying additional sites in order to increase capacity. We assume that if the MNO can achieve a certain threshold of cost savings through obtaining additional spectrum, then the operator will seek to obtain it. Therefore, in order to calculate the demand for spectrum, we have developed a cost model for an MNO's network to compare the differences in cost incurred when it has different quantities of spectrum available.

An overview of our modelling approach is displayed below in Exhibit 0.3. This methodology is based on the approach used for quantifying future spectrum demand for cellular services during Analysys's recent study for the IASH in the UK.



**Exhibit 0.3:** Calculation of an MNO's spectrum requirements [Source: Analysys, 2005]

To model future spectrum demand, we need to make an assumption about the cost threshold at which operators would demand more spectrum – essentially, what the value of spectrum increment, e.g. 2×5MHz, will be in the future.

The report also includes an overview of the current methodology used by the ITU-R and discusses the differences between the two approaches.

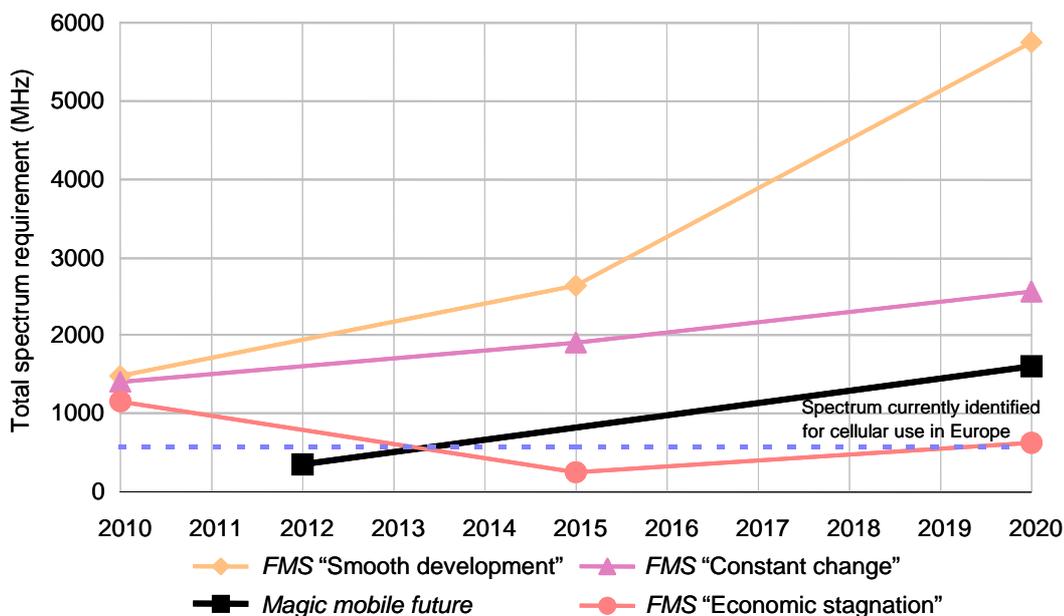
### *Scenarios*

We have used the *Magic mobile future* forecasts and the three scenarios in the *FMS* study (“constant change”, “smooth development” and “economic stagnation”) as our base-case scenarios. We have then run a number of scenarios, as outlined below:

- **Busy hour** – The base case for the proportion of daily traffic that falls in the busy hour is set to be 7.5%. However, we have also assessed the impact of using 10% as a high scenario.
- **Improvements in spectral efficiency** – In our base case, we have assumed that, in 2020, the improvement in spectral efficiency will be ten times that of UMTS technology today; however, we have also run low and high scenarios where this figure is five times and twenty times respectively.
- **Cost-saving threshold** – We have assumed the cost-saving threshold in our base case to be EUR7.5 million per 2×5MHz in 2005. This value was used by Analysys in its recent study for the IASH in the UK. This value was chosen to be representative for a Western-European country. However, we have also included scenarios in which this threshold is EUR3 million and EUR15 million.
- **Non-IMT-2000/systems beyond IMT-2000 traffic (*FMS* study only)** – In our base case, we have assumed that, in 2005, 50% of the traffic projected in the *FMS* study is carried over IMT-2000/systems beyond IMT-2000 networks and that this rises to 70% in 2020. This assumption was agreed in discussions with the UMTS Forum. We have also calculated spectrum demand for the case where the traffic carried over cellular networks remains at 50% until 2020.

## 0.4 Spectrum-requirement forecasts

Using the traffic profiles with our base-case assumptions, the total spectrum forecasts calculated, including existing spectrum used for mobile services, are given in Exhibit 0.4 below.



**Exhibit 0.4:** Spectrum requirements calculated using the spectrum forecasts<sup>3</sup> in Europe  
 [Source: Analysys, Magic mobile future, FMS, 2005]

The *FMS* scenario for “constant change” has significantly higher spectrum demand between 2010–2020 than the *Magic mobile future* study. This is due to the fact that the *FMS* study assumes higher growth in traffic earlier than the *Magic mobile future* study. The *FMS* scenario for “constant change” yields a spectrum demand in 2020 that is 50% greater than the *Magic mobile future* forecast. Meanwhile, using the “smooth development” scenario results in a forecast requirement in 2020 that is more than three times as large as the *Magic mobile future* forecast.

<sup>3</sup> The spectrum currently identified for cellular use is 585MHz and includes the 900MHz and 1800MHz GSM bands, the 2GHz UMTS band (including the band that is currently used for DECT), and the 2.5GHz expansion band.

In the “economic stagnation” scenario, there is a substantial reduction in spectrum between 2010 and 2015, before increasing again by 2020 to 640MHz. This is because, after some sharp increases in traffic in the years before 2010, the volume then decreases due to the onset of a period of economic decline. Note that, even though in the “economic stagnation” scenario we assume that operators continue to build out their networks and invest in more spectrally efficient technologies (e.g. systems beyond IMT-2000), this may not occur in practice, in which case the spectrum demand in this scenario will be higher.

Our scenarios have also illustrated a number of factors that may influence these spectrum requirements:

- **The busy-hour assumption** – If the busy-hour assumption is increased from 7.5% to 10%, then the spectrum requirements in 2020 rise from 1.6GHz to 1.9GHz (20%) when using the *Magic mobile future* traffic forecast, and increase from 2.6GHz to 2.9GHz (13%) when using the *FMS* “constant change” traffic forecast. Offering a service mix and pricing that results in a situation where the traffic is distributed as evenly as possible over the day would help to minimise the spectrum requirement.
- **Improvement in spectral efficiency** – If the assumed improvement in spectral efficiency, which is already substantial, is assumed to be even greater (e.g. doubled by 2020), then the spectrum requirements in 2020 would be reduced. Consequently, the spectrum requirements fall from 1.6GHz to 1.0GHz (40%) when using the *Magic mobile future* traffic forecast, and from 2.6GHz to 1.6GHz (38%) when using the *FMS* “constant change” traffic forecast. This underlines the requirement for the development of new, more spectrum-efficient technologies.
- **Cost-saving threshold** – If the cost-saving threshold assumption is reduced from EUR7.5 million to EUR3 million, then the spectrum demand in 2020 increases from 1.6GHz to 2.2GHz (40%) when using the *Magic mobile future* traffic forecast, and from 2.6GHz to 3.2GHz (25%) when using the *FMS* “constant change” traffic forecast. Similarly, if this assumption is increased to EUR15 million, then the spectrum demand in 2020 decreases from 1.6GHz to 1.3GHz (20%) when using the *Magic mobile future* traffic forecasts, and from 2.6GHz to 1.9GHz (25%) when using the *FMS* “constant change” traffic forecast.

- **The traffic assumptions applied to the *FMS* study traffic forecasts** – If the proportion of overall mobile traffic that is assumed to be served via IMT-2000 or systems beyond IMT-2000 remains at 50% until 2020, then the cellular spectrum requirement in 2020 decreases from 2.6GHz to 1.9GHz (25%) by 2020. If this were to occur, more spectrum would need to be allocated to other technologies (e.g. WLANs).

## 0.5 Conclusions

Both market studies used as inputs to these calculations predict significant growth in mobile traffic until year 2020. Our results suggest that if these traffic projections were realised, the spectrum requirements for cellular services would be much higher than the amount of spectrum currently allocated for cellular use in Europe.<sup>4</sup>

Using the traffic profile forecasts in the *Magic mobile future* study, we calculate that, in our base case, the total demand for cellular spectrum will be 1.6GHz by 2020.

Using the traffic forecasts from the “constant change” scenario in the *FMS* study (the scenario that was used in CEPT’s contribution to the ITU-R as European Market Data), we calculate the total demand to be 2.6GHz by 2020.

Finally, it should be noted that this study is based on the *Magic mobile future* traffic forecasts for a *representative* Western-European country and on *FMS* traffic forecasts for “EU25 plus accessions”. Therefore, those Western-European countries with traffic demand and urban population density that are higher than average may require more spectrum than we have calculated in this study.

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<sup>4</sup> The spectrum currently identified for cellular use is 585MHz and includes the 900MHz and 1800MHz GSM bands, the 2GHz UMTS band (including the band that is currently used for DECT) and the 2.5GHz expansion band.

# 1 Introduction

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## 1.1 Background and objectives

The European cellular market is currently implementing UMTS networks and services. Beyond this, the industry is already looking ahead towards the future (the systems beyond IMT-2000). One of the key questions for cellular operators and regulators alike is what will be the spectrum requirements for these services in the future?

Forecasting future spectrum requirements is complex and requires an understanding of the future evolution of a number of parameters:

- Firstly, there is uncertainty over how spectral efficiency will improve over time. Many cellular operators are likely to invest in the deployment of high-speed downlink packet access (HSDPA) and high-speed uplink packet access (HSUPA) technologies in the next few years. However, beyond that, further improvements are less well defined (e.g. long-term evolution (LTE), systems beyond IMT-2000, etc.).
- Secondly, a range of alternative technologies (e.g. WLAN and mobile broadcast technologies, such as 802.11 and DVB-H) may be deployed to complement UMTS and/or systems beyond IMT-2000.

- Thirdly, future spectrum requirements are dependent on the future demand for cellular services and the traffic they generate. The UMTS Forum and the European Commission (EC) have commissioned studies to investigate the future demand for these services and the resulting traffic generated. These studies are the *Magic mobile future 2010-2020*<sup>5</sup> and *The demand for future mobile communications markets and services in Europe (FMS)*<sup>6</sup> respectively, both of which were published in April 2005.

The objective of the present study is to calculate the future demand for spectrum from IMT-2000 and systems beyond IMT-2000, up until 2020, using the traffic profiles forecast in the *Magic mobile future* and *FMS* studies mentioned above. Our methodology is based on the approach used for quantifying future spectrum demand for cellular services during Analysys's recent study for the Independent Audit of Spectrum Holdings (IASH) in the UK.<sup>7</sup>

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**Please note that the spectrum forecasts that are produced in this report are highly dependent on the traffic forecast inputs from the *Magic mobile future* and *FMS* studies; Analysys was not involved in the development of these traffic forecasts.**

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## 1.2 Structure of this report

The remainder of this report is structured as shown in follows:

<i>Chapter</i>	<i>Summary</i>
Chapter 2	Summarises the <i>Magic mobile future</i> and <i>FMS</i> studies and the methodology that has been used to forecast future mobile traffic
Chapter 3	Outlines the methodology we have used to calculate future spectrum demand, including a comparison with the methodology used by the ITU-R
Chapter 4	Contains the results of our spectrum-demand calculations
Chapter 5	Presents our overall conclusions from the study
Annex A	Provides further details on the methodology and calculations employed in our study
Annex B	Provides details and sources for the documents that have been used in the preparation of this study

**Exhibit 1.1:** *Structure of the report*

<sup>5</sup> [www.umtsforum.org](http://www.umtsforum.org).

<sup>6</sup> <http://fms.jrc.es/documents/FMS%20FINAL%20REPORT.pdf>.

<sup>7</sup> See [www.spectrumaudit.org.uk](http://www.spectrumaudit.org.uk) or [www.analysys.com](http://www.analysys.com) for further details of this study.

## 2 Description of the traffic forecasts

This chapter provides a summary of the two studies used in this report for the traffic forecast inputs: *Magic mobile future 2010-2020* and *The demand for future mobile communications markets and services in Europe (FMS)*. It includes an overview of the methodology that each study used to forecast future mobile traffic.

### 2.1 Magic mobile future 2010-2020

This study was conducted by the UMTS Forum and published in April 2005. Its aim was to assist the ITU-R in the process for the preparatory work for the WRC-07 under agenda item 1.4, concerning the long-term market forecasts needed to determine spectrum requirements for IMT-2000 and systems beyond IMT-2000. A key output of the report is a traffic forecast for a typical representative European country.

The report used a three-step methodology to create these forecasts:

#### 2.1.1 Step 1 – Trends

The report identified some broad trends that will shape the world from 2010 to 2020, along with a number of technology trends that will shape future mobile devices and networks:

*Key drivers that will shape the world of 2010-2020*

The key drivers will be:

- more urban and more aged population
- labour-force evolution will lead to new needs for communication
- privacy and education are identified as social trends
- the ICT environment booming everywhere; dramatic growth in Asia.

- Key technology trends*
- Mobile devices will benefit from major breakthroughs expected to occur in the next decade: technology developments in areas such as semiconductors, nanotechnology, processing power and storage capacity will enable the emergence of smaller, increasingly complex and intelligent devices. However, battery power technology will only improve in terms of power to weight ratios, rather than any generational improvements.
  - Many networking technologies will be available to enable true ubiquitous mobile access: many technologies will become available that provide different wireless solutions (e.g. wireless sensor networks, “enhanced 3G”) and networking protocols will connect users to the best available network.

The report also reviewed the possible trends of some emerging mobile services:

- Object identification, sensor networks and machine-to-machine (M2M)*
- Miniaturisation will enable wireless tags, beacons and sensor nodes may enable the number of connected points, products and machines to exceed the number of connected people (billions of units in a year). This will enable a host of new services: homes will be “sensorised” with remote monitoring and control over refrigerator inventory, environmental controls and parental control of content.
- Health monitoring*
- Mobile devices will enable the transmission of health information to a server maintained by individual or healthcare providers for analysis. From a niche-market in 2010, adoption will expand to routine monitoring and sophisticated analysis by 2020.
- Location discovery*
- Future technologies such as wireless beacons are likely to provide location information potentially to the nearest few centimetres.
- M-payment and micro-commerce*
- By the next decade, the technologies required for initiating the transaction, the mobile transaction authentication and payment reconciliation will be available.

<i>Digital content</i>	Mobile technology will be in place to meet consumers' demand for rich digital content anytime, anywhere and over any channel.
<i>Mobile entertainment</i>	The user will have access to entertainment media wherever and whenever desired, and will have increasing ability to customise their own entertainment experience.
<i>Corporate services</i>	Mobile technologies like virtual private networks (VPNs) or M2M services will enable the increased blurring of home and work life. Working hours are likely to become more flexible as a result.
<i>M-government</i>	Government will encourage the adoption of technology by proactively using technology to disseminate information and provide services.
<i>M-education</i>	This would be a second step in the digitalisation of education that was decided by many governments.

### 2.1.2 Step 2 – Scenarios

A modelling framework was then developed to produce three different but possible scenarios that represent the possible outcomes of the future of mobile communications. These are summarised below:

- **Scenario 1: Low price, voice-dominated growth** – A pessimistic scenario that describes the mobile industry evolving into bigger volumes rather than enhanced capabilities. Voice increases in volume but revenues diminish, and are not replenished by the adoption of new applications. Overall, communications industry revenues decline as all pricing levels continue to fall.
- **Scenario 2: Balanced, broad-based growth** – Mobile networks deliver compelling new services such as anytime, anywhere streaming video customised to the needs of users. Business integrate mobile deeply into their operational practices. Other communications industry service providers are effectively converged into mobile-led companies, whilst content and application providers find a healthy, growing market place.

- **Scenario 3: Pervasive data-driven growth** – Ad-hoc broadband wireless networks, with many services that are close to free in urban areas, start to take a significant part of the traffic. Traffic volumes increase as the cost of access falls dramatically. Users have multiple options to connect, though seamless experiences are not guaranteed. The larger mobile networks ensure complementary coverage on a national level to these ad-hoc networks.

### 2.1.3 Step 3 – Traffic forecasts

The study concluded that Scenario 2 was the most plausible; this was used to develop traffic forecasts for 2012 and 2020 for a representative Western-European country of approximately 11 million people.

In order to develop these traffic forecasts, the study has used a bottom-up approach to model the future traffic for six main service groups: multimedia messaging; simple and rich voice; customised infotainment; mobile Internet access; mobile intranet access; and location-based services. For each service group, the number of subscribers and usage was forecast for each year and the total traffic was calculated. The approach for multimedia messaging is described in the next section as an example.

#### *Calculation example: multimedia messaging*

The study firstly calculated the number of subscribers by segment for 2012 and 2020, as illustrated in Exhibit 2.1 below. It forecast the total number of subscribers to grow by 12 million.

<i>Segment</i>	<i>2012 (millions)</i>	<i>2020 (millions)</i>
Consumers	7.1	12.4
Business	11.5	25
Telemetry	60	53.1
M2M	0	24.4
<b>Total</b>	<b>78.6</b>	<b>90.5</b>

#### **Exhibit 2.1:**

*Subscriptions*

*[Source: Magic*

*mobile future, 2005]*

The total number of messages per month per user was then forecast to be flat over the forecast period, but the mix of messages would move towards message formats of larger sizes. This is illustrated in Exhibit 2.2 below.

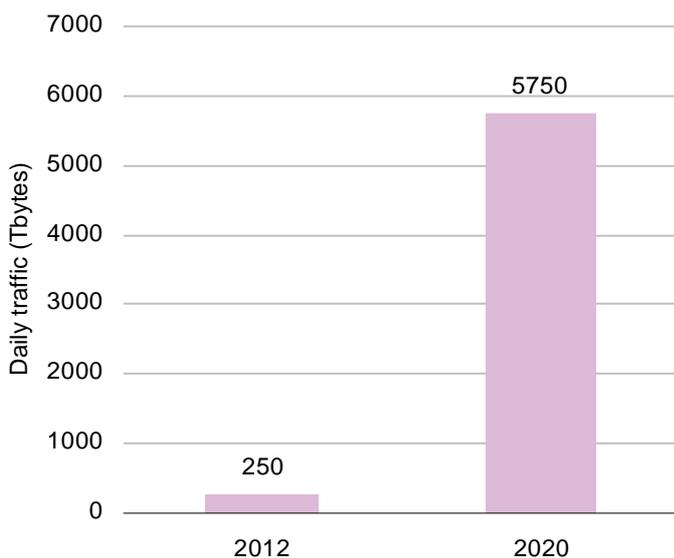
Message format	2012	2020
Text	218	33
Photo	79	148
Video	33	148
<b>Total</b>	<b>330</b>	<b>329</b>

**Exhibit 2.2:**  
*Messages per month per user*  
 [Source: Magic mobile future, 2005]

From these subscription and usage forecasts, the report forecasts the future daily traffic for multimedia messaging to be 5744Tbytes in 2020, and the busy-hour traffic to be 411Tbytes.

*Total traffic forecast*

The report combined the traffic forecasts for each service to produce total mobile traffic forecasts for the representative European country. This is illustrated in Exhibit 2.3 below.



**Exhibit 2.3:**  
*Daily traffic for representative European country*  
 [Source: Magic mobile future, 2005]

## 2.2 Demand for future mobile communications markets and services in Europe (*FMS*)

This study was conducted by the Institute for Prospective Technological Studies (IPTS) on behalf of the EC to aid Europe in its preparations for the WRC-07. It was published in April 2005. The study's aim was to explore the way people will use future wireless communications services over mobile networks and to forecast the traffic that will be generated in the European Union (EU)<sup>8</sup> by 2010, 2015 and 2020.

The study developed three potential future scenarios based on socio-economic principles:

- **Scenario 1: Smooth development** – EU economies unite to provide constant growth and development in a fair and managed way that brings prosperity across all 25 members plus Bulgaria, Croatia and Romania.
- **Scenario 2: Economic stagnation** – The EU economy slowly declines, as the Japanese economy did between 1998 and 2003. Outputs generally shrink and the reactions of government policy to strong deflation are unsuccessful or frozen.
- **Scenario 3: Constant change** – Overall, the economy follows a moderately positive trend, with ups and downs. Ad hoc growth and recession often occur in parallel in different areas or countries. However, prosperity slowly increases for many in the EU.

A questionnaire was conducted of industry stakeholders and other experts and academics to assess the plausibility of the three scenarios. The majority of the 43 respondents to the study considered the “constant change” scenario as the most plausible, which was later chosen as the basis of the market input from the CEPT to the ITU-R.

The traffic forecasts for each of these scenarios were calculated using a three-step process:

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<sup>8</sup> Defined as the EU25 plus Bulgaria, Croatia and Romania.

### 2.2.4 Step 1: Segmentation

Users were split into two main categories: consumers and enterprises. The consumers were then segmented by income and age, whilst the enterprises were segmented into the size of the organisation and whether it is in the service sector or not. In total, the report defined 15 categories, as shown in Exhibit 2.4 below:

<b>Consumers</b>	
▪ Low income: age 0–14	▪ Medium income: age 65+
▪ Low income: age 15–64	▪ High income: age 0–14
▪ Low income: age 65+	▪ High income: age 15–64
▪ Medium income: age 0–14	▪ High income: age 65+
▪ Medium income: age 15–64	
<b>Enterprises</b>	
▪ Micro – service sector	▪ SME – non-service sector
▪ Micro – non-service sector	▪ Large enterprises – service sector
▪ SME – service sector	▪ Large enterprises – non-service sector

**Exhibit 2.4:** User categories [Source: FMS, 2005]

### 2.2.5 Step 2: Creation of “baskets of services”

The study identified 139 different existing or future mobile services (e.g. voice, location nearest point of interest, handset location and tracking for anti-theft and fraud). These were grouped into four “baskets of services” based on users’ needs and motivations. For consumers, these were “lifestyle”, “communications” and “entertainment”; for enterprises, this was “business applications”.

### 2.2.6 Step 3: Calculation of traffic volume

For each user segment, the average number of communication sessions per day and the average duration of each session was forecast for each “basket of services” for 2010, 2015 and 2020. These were then multiplied by the typical bit rate for each “basket of services” and the number of users in each segment in the EU; this was repeated for each of the three scenarios.

An example of the calculation for consumers of medium income aged 15-64 for the “constant change” scenario in 2020 is shown in Exhibit 2.5 below.

	<i>Communications</i>	<i>Entertainment</i>	<i>Lifestyle</i>
Minutes of usage per day	15	60	40
Bit rate (kbit/s)	2000	2000	2000
Daily traffic per user (mins of 1Mbit/s)	30	120	80
Number of users (millions)	208.5	208.5	208.5
Daily traffic (millions of mins of 1Mbit/s)	6254	25 017	16 678

**Exhibit 2.5:** *Traffic calculation for consumers of medium income aged 15-64 for the “constant change” scenario in 2020 [Source: FMS, 2005]*

Traffic forecasts for each segment and “basket of services” were combined for each year to produce the total forecast traffic.

#### *Traffic forecasts*

In the “smooth development” scenario, the need for sophisticated services such as education support was deemed to be more important, whereas in the “economic stagnation” scenario low-cost services aimed at more basic lifestyles were more important. In the “constant change” scenario, the need arose for wireless services as an essential link for migrant workers to maintain family ties and organise a new life away from their home countries.

The total traffic forecasts for the EU for each scenario are shown in Exhibit 2.6 below.

	<i>Smooth development</i> <i>(millions of mins of 1Mbit/s)</i>	<i>Economic stagnation</i> <i>(millions of mins of 1Mbit/s)</i>	<i>Constant change</i> <i>(millions of mins of 1Mbit/s)</i>
2010	27 400	21 236	27 554
2015	137 141	15 210	111 426
2020	918 026	56 709	332 630

**Exhibit 2.6:** *Traffic forecasts by scenario [Source: FMS, 2005]*

In the “economic stagnation” scenario, total traffic is forecast to fall between 2010 and 2015; it is then expected to grow until 2020. The traffic forecasts for the “smooth

development” and the “constant change” scenarios are comparable in 2015; it is only after 2015 that differences in traffic volumes are expected to become apparent.

#### *“Activity ratios”*

The data-rate assumptions made in the *FMS* study are actually maximum bit rates required for the services. In reality, the actual traffic generated by the services will be lower. Following the publication of this study, an “activity ratio” was applied to the forecasts to account for inactive “silent periods” during users’ sessions. This factor should be taken into account in any spectrum-demand calculation.

#### *Considerations regarding the calculation of spectrum requirements using the FMS study traffic forecasts*

It should be noted that the forecasts in the *FMS* study include traffic for services that are likely to be served via technologies/networks other than IMT-2000 and systems beyond IMT-2000 (e.g. WLAN, broadcast mobile networks). Therefore, it was necessary to exclude this traffic in spectrum-demand calculations for IMT-2000 and systems beyond IMT-2000.

## 3 Spectrum forecast methodology

In this chapter we give an overview of the approach that we have used to calculate spectrum demand (Section 3.1); we compare it with the ITU-R's methodology for calculating spectrum demand (Section 3.2); and we introduce the scenarios that are used in our modelling (Section 3.3).

### 3.1 Overview of approach

In order to develop an understanding of how demand of cellular spectrum will evolve over the next 15 years, the study takes the perspective of a mobile network operator (MNO). This is to understand the motivations that may compel an operator to seek a larger spectrum assignment. Enhancements to a mobile operator's network are determined by consumer demand and the capabilities of its present network: an MNO will most probably seek to develop its network in the most cost-efficient manner possible.

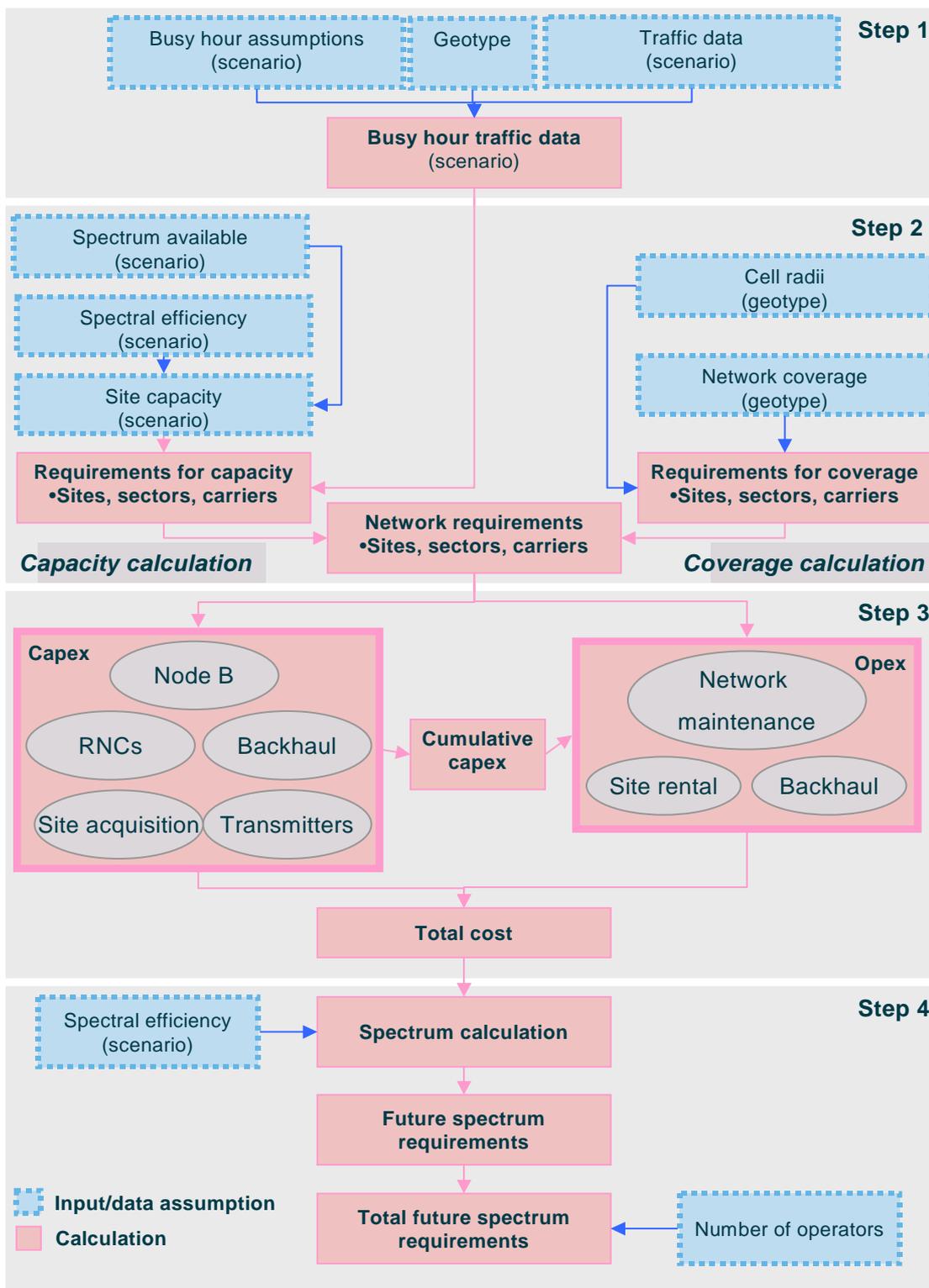
In the event of traffic increasing on the network, capacity can be increased by either:

- obtaining more spectrum and deploying a new carrier in this spectrum at base-station sites where there are capacity shortages
- deploying additional base-station sites in areas where the demand for capacity exceeds current availability.

In reality, an MNO faces a trade-off between the two in order to minimise its expenditure. We assume that if a certain threshold of cost savings can be achieved by the MNO through obtaining additional spectrum, then the operator will seek to obtain it.

Therefore, in order to calculate the demand for spectrum, an understanding of the cost base of cellular networks is required, specifically those costs that vary depending on the spectrum held by the MNO. To this end, we have developed a cost model for an MNO's cellular network to compare the differences in cost incurred by the MNO depending on the use of different quantities of spectrum. Currently, with UMTS, these units of spectrum are 2×5MHz carriers, however, the carrier size is forecast to increase with future technologies.

An overview of our modelling approach is displayed below in Exhibit 3.1.



**Exhibit 3.1:** Calculation of an MNO's spectrum requirements [Source: Analysys, 2005]

Our approach involves four steps:

- **Step 1: Transforming the traffic profiles into the required format** – The traffic forecasts in the two reports under consideration were translated into busy-hour traffic forecasts and broken down by geographical areas based on population density zones (geotypes).
- **Step 2: Calculation of number of sites** – In this step we calculate the number of sites required for coverage, which is calculated as the area required for coverage divided by the maximum area per site; we also calculate the number of sites required for capacity, which is calculated by the traffic demand divided by the traffic capacity per site. Both of these calculations are conducted by geotype. The traffic capacity per site, and hence the number of sites that an operator will deploy for capacity, is dependent on the amount of spectrum that it has available. The more spectrum an operator has available, the less sites will be required.
- **Step 3: Cost calculation** – As the number of sites changes with the amount of spectrum, there are several costs that will also vary. These include upfront capital expenditure costs (site acquisition, Node Bs, transmitters, radio network controllers (RNCs), backhaul capex) as well as ongoing operating expenditure costs (site rental, backhaul opex, additional network maintenance).
- **Step 4: Calculation of spectrum demand** – For each year, the total capex and opex is calculated for a range of spectrum available to the operator, under each of the traffic scenarios. If the cost saving in a given year from having an additional block of spectrum is greater than a certain threshold, then it is assumed that the operator would demand that additional spectrum.

A more detailed description of the methodology that we have followed is included in Annex A of this report. This also includes an explanation of how the traffic forecasts discussed in Chapter 2 were translated into an appropriate format for our modelling work.

### 3.1.1 Cost-saving threshold

To model future spectrum demand, we need to make an assumption about the cost threshold at which operators would demand more spectrum – essentially what the value of spectrum will be in the future.

Please note that this study does not assume that spectrum is available to be traded or that it can be bought, although this may be the case soon in some countries. However, the supply of spectrum is limited, therefore, it has an intrinsic value. In countries in which spectrum trading is not in place, this can be viewed as an opportunity cost. Regulators in these countries will balance the benefit of using spectrum for cellular use versus other uses.

For the purposes of this study, we have used the same cost-saving threshold as the one used in our work for the IASH in the UK, which was EUR7.5 million (GBP5 million) per annum per 2×5MHz of spectrum. Therefore, if the cost saving that an operator can make in an individual year is larger than this value, we assume that the operator will demand extra spectrum. Of course, the value of spectrum will vary between countries but this value has been chosen to be representative. We have included scenarios in our results (Section 4.2) using values of EUR3 million and EUR15 million.

### 3.1.2 Scope

We have modelled the spectrum demand for a representative EU country and developed our model from the perspective of a single MNO in a market where there are four operators (i.e. each operator is assumed to have a 25% market share). The aggregate spectrum demand for the whole country is then obtained by multiplying the outputs for an individual operator by four. However, it should be noted at this point that the number of operators modelled is only critical to the results if the spectrum demand is very low.

We have focussed on forecasting the spectrum requirements for networks employing IMT-2000 and systems beyond IMT-2000 technologies. However, we have assumed that operators will also require spectrum to operate GSM networks in 2010 and 2012. We have assumed that these GSM networks will be decommissioned before 2015. The total spectrum requirement is calculated by adding the GSM spectrum demand to the demand for spectrum for IMT-2000 and systems beyond IMT-2000.

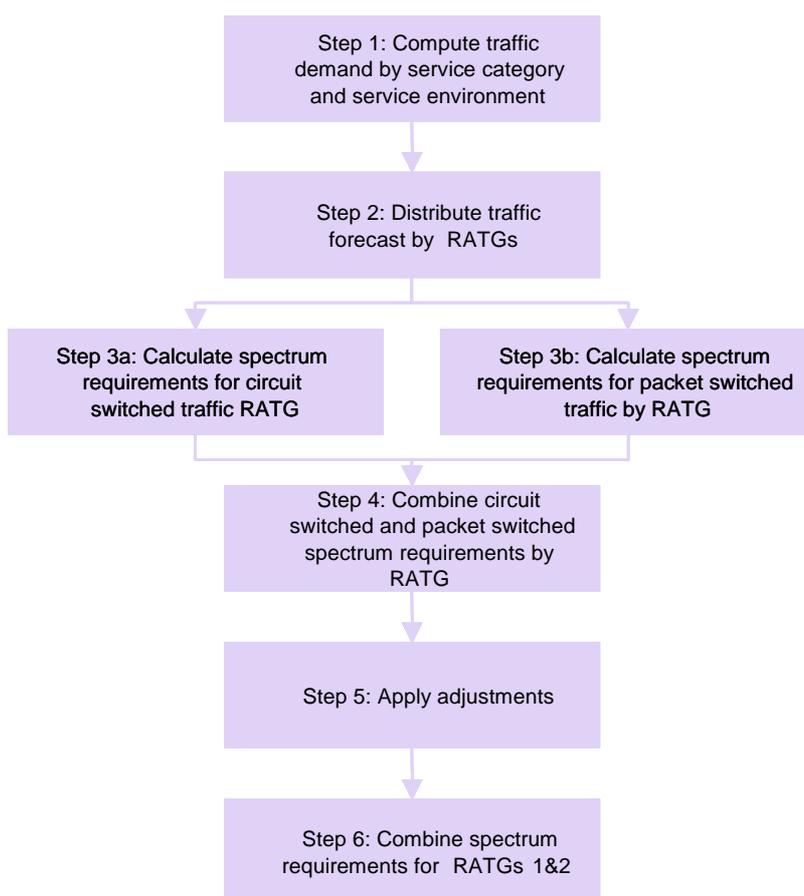
## 3.2 Comparison with ITU-R's spectrum calculation methodology

In this section, we give an overview of the methodology that the ITU-R uses to calculate future spectrum demand (Section 3.2.1) and we then compare this methodology to that used in this study (Section 3.2.2).

### 3.2.1 Overview of the ITU-R spectrum calculation methodology

In document 8/113-E, dated 10 November 2005, the ITU-R describes its methodology to calculate the future spectrum requirements of IMT-2000 and systems beyond IMT-2000. At the time of writing, this work has been adopted by Study Group 8, but is yet to be published.

An illustration of the approach used by the ITU-R is shown in Exhibit 3.2 below:



**Exhibit 3.2:**  
ITU-R's spectrum calculation methodology  
[Source: ITU-R, Analysys, 2005]

The approach involves a six-step process as described below.

*Step 1: Compute traffic demand by service category and service environment*

The ITU-R defines 20 “service categories” based on combinations of “service types” (super high multimedia; high multimedia; medium multimedia; low-rate data and low multimedia; and very low-rate data) and “traffic classes” (conversational; streaming; interactive and background). It is assumed that all traffic occurring in the conversational and streaming “traffic classes” are circuit-switched, whilst the interactive and background classes are packet-switched.

The ITU-R also defines six “service environments” (dense urban – home; dense urban – office; dense urban – public area; suburban – home; suburban – office/public area; and rural). Market research is conducted to develop traffic forecasts for each combination of service category and service environments.

*Step 2: Distribute traffic forecasts by radio access technology group (RATG) and radio environment*

The ITU-R defines four RATGs:

- Group 1: Pre-IMT systems, IMT-2000 and its enhancements
- Group 2: Systems beyond IMT-2000
- Group 3: Existing radio local area networks (LANs) and their enhancements
- Group 4: Digital mobile broadcasting and their enhancements.

It also defines four “radio environments”: macro cells, micro cells, pico cells and hot spots. Each of these is assigned different performance characteristics (cell traffic capacity, cell radius, etc.)

The traffic forecast is split between these four RATGs using distribution ratios (the proportion of traffic that is serviced via each RATG in areas where more than one RATG is available). Only the traffic allocated to RATG 1 and RATG 2 is then considered further in their spectrum calculations. The traffic is also split between the four “radio environments”.

*Step 3: Calculate spectrum requirement by traffic type and RATG*

The spectrum-demand calculation for circuit-switched and packet-switched traffic is calculated separately for both RATG 1 and RATG 2 and for each “radio environment”.

The spectrum demand for circuit-switched traffic is determined by the number of service channels that are needed to achieve the required blocking probability and channel data rate. The spectrum demand for packet-switched traffic is calculated using a queuing model, in which the capacity per cell is determined by the acceptable mean delay by service category. Again, the number of cells is effectively given as an input.

*Step 4: Combine circuit-switched and packet-switched spectrum requirements by RATG*

The spectrum requirements for the circuit-switched and packet-switched traffic are simply added together to produce initial spectrum requirements for both RATG 1 and RATG 2. The spectrum requirements for each radio environment are also combined.

*Step 5: Apply adjustments*

A number of adjustments are then applied to these initial spectrum requirements to take into account spectrum sharing between operators, the minimum carrier size, the fact that pico cells and hotspots do not overlap geographically (therefore their spectrum demands are not additive) and guard bands.

*Step 6: Combine spectrum requirements for RATG 1 and RATG 2*

The spectrum requirements for RATG 1 and RATG 2 are then combined to produce a total spectrum requirement.

### 3.2.2 Comparisons between the methodologies of the ITU-R and Analysys

This section discusses the differences between the ITU-R's and Analysys's approach and the impact that these differences will have on the spectrum-demand results. Please note that this excludes discussion about the differences between the methodologies to forecast future traffic as this was an input into our approach as provided by the *Magic mobile future* and *FMS* studies.

The main differences between the two methodologies are:

- The ITU-R's approach calculates the spectrum demand for circuit-switched traffic separately to packet-switched traffic. This takes into account the fact that not all services require traffic to be delivered instantaneously and that some services (e.g. email) permit delays in the arrival of traffic, thus reducing the spectrum requirement. These two types of traffic are not split out in the approach adopted by Analysys, however, this effect is taken into account in the busy-hour assumptions that have been used. We have assumed a lower busy-hour assumption for our base case (7.5%) than has traditionally been used in circuit-switched models to reflect the fact that more traffic is likely to occur outside the busy hour than historically. Therefore, the difference in spectrum demand caused by this difference should not have a significant impact on the results.
- The ITU-R's methodology splits the traffic demand by "radio environments" (macro cells, micro cells, pico cells and hot spots). It includes different cell capacities and radii for each environment and calculates the spectrum demand for each before combining them to produce a total spectrum requirement. Analysys's methodology does not split the traffic forecasts into different types of cells (nor are the traffic forecasts available at this level of granularity). However, we have assumed different site capacities and cell radii for each geotype to reflect the mix of these different types of radio environments. For example, we have assumed that the average site capacity in dense urban areas is 50% higher than in rural areas in 2020 to reflect the fact that a number of micro/pico cells are likely to be deployed in these areas. Therefore, the difference in spectrum demand caused by this difference should not have a significant impact on the results.
- The ITU-R's methodology effectively assumes that the number of sites is fixed, whereas Analysys's approach uses this as a variable that changes depending on the amount of spectrum that is available. Therefore, using high-traffic scenarios, the

approach used by Analysys is likely to produce lower spectrum demand as operators will deploy some extra sites in order to cope with the high traffic demand and, as a result, will require less spectrum than if the number of sites was fixed. Conversely, using low-traffic scenarios, Analysys's approach is likely to produce higher spectrum demand as operators will deploy less sites.

- The ITU-R's methodology has the ability to include adjustments for operators sharing spectrum. Analysys's approach does not account for this, which may mean that Analysys's approach produces higher spectrum requirements.
- The ITU-R's methodology has the ability to include guard bands. Analysys's approach does not, which may mean that the approach adopted by Analysys produces slightly lower spectrum requirements.

### 3.3 Scenarios

We have used the *Magic mobile future* forecasts and the three scenarios in the *FMS* study ("constant change", "smooth development" and "economic stagnation") as our base-case scenarios. We have then run a number of scenarios, as outlined below.

#### *Scenario 1: Non-IMT-2000/systems beyond IMT-2000 traffic*

To take account of traffic that is transmitted over WLAN and broadcast mobile infrastructures, we have assumed that, in 2005, 50% of the traffic projected in the *FMS* study is carried over IMT-2000/systems beyond IMT-2000 networks and that this rises to 70% in 2020. This assumption was agreed in discussions with the UMTS Forum. If this assumption overstates the amount of traffic that will be transmitted over IMT-2000/systems beyond IMT-2000 networks, then this will in turn overstate the amount of spectrum required. We have also calculated spectrum demand for the case where the traffic carried over cellular networks remains at 50% until 2020.

Again, this factor is only applied to the *FMS* study forecasts and, therefore, this scenario is not applied to the *Magic mobile future* traffic forecasts.

### *Scenario 2: Busy hour*

The base case for the proportion of daily traffic that falls in the busy hour is set to be 7.5%. However, we have also assessed the impact of using 10% as a high scenario.

This scenario has been applied to the *Magic mobile future* and the *FMS* “constant change” forecasts. Please note that the *Magic mobile future* study includes a busy-hour assumption of 7.5%; therefore, this is comparable with our base-case scenario.

### *Scenario 3: Improvements in spectral efficiency*

This section discusses our assumptions for future improvements in spectral efficiency. We have developed three alternative scenarios which take account of future levels of spectral efficiency improvements over the next 15 years, resulting from the introduction of new technologies such as HSDPA/HSUPA, LTE and systems beyond IMT-2000. The first series of assumptions are in relation to the timing of deployment of these enhancing technologies, which are presented in Exhibit 3.3 below.

<i>Technology</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
HSDPA/HSUPA	✓	✓	✓	✓
LTE	✗	✓	✓	✓
Systems beyond IMT-2000	✗	✗	Partially deployed	✓

**Exhibit 3.3:** *Timeline for deployment of new technologies [Source: Analysys, 2005]*

Once each technology has been deployed, there is an improvement in the spectral efficiency of each carrier on the mobile network, when compared with the capacity obtained from UMTS today. Exhibit 3.4 below presents the three scenarios of improvement that we have assumed in our scenarios over the current performance of UMTS.

Scenario	HSDPA/HSUPA	LTE	Systems beyond IMT-2000
Low	1.75 times	2.25 times	5.0 times
Medium	2.25 times	3.25 times	10.0 times
High	3.25 times	5.25 times	20.0 times

**Exhibit 3.4:** *Improvements in base-station capacity upon deployment of various technologies versus UMTS release 4 (pre-HSDPA) [Source: Analysys, 2005]*

#### *Scenario 4: Cost-saving threshold*

As discussed in Section 3.1, we have assumed the cost-saving threshold in our base case to be EU7.5 million per 2×5MHz in 2005. However, we have also included scenarios in which this threshold is EUR3 million and EUR15 million. In each of our scenarios we have assumed that this threshold will increase with inflation over time.

### 3.4 Summary of base case

In summary, the nature of the inputs in our base cases is displayed below in Exhibit 3.5.

Report	FMS scenario	Proportion of traffic over cellular network
<i>Magic mobile future</i>	n/a	n/a (100%)
<i>FMS</i>	Constant change	70% by 2020
<i>FMS</i>	Smooth development	70% by 2020
<i>FMS</i>	Economic stagnation	70% by 2020

**Exhibit 3.5:**  
*Summary of the main inputs in the two base cases*  
 [Note: n/a means not applicable]  
 [Source: Analysys ]

In each of these base cases we have also assumed that 7.5% of traffic occurs in the busy hour, spectral efficiency improves ten-fold by 2020 (versus UMTS release 4 (pre-HSDPA)) and that the cost-saving threshold is EUR7.5 million per 2×5MHz in 2005.

Note that, even though in the “economic stagnation” scenario we assume that operators continue to build out their networks and invest in more spectrally efficient technologies (e.g. systems beyond IMT-2000), this may not happen, in which case the spectrum demand in this scenario will be higher.

Our scenarios are then based around varying these inputs and considering the resulting changes in the spectrum requirement.

## 4 Spectrum requirement forecasts

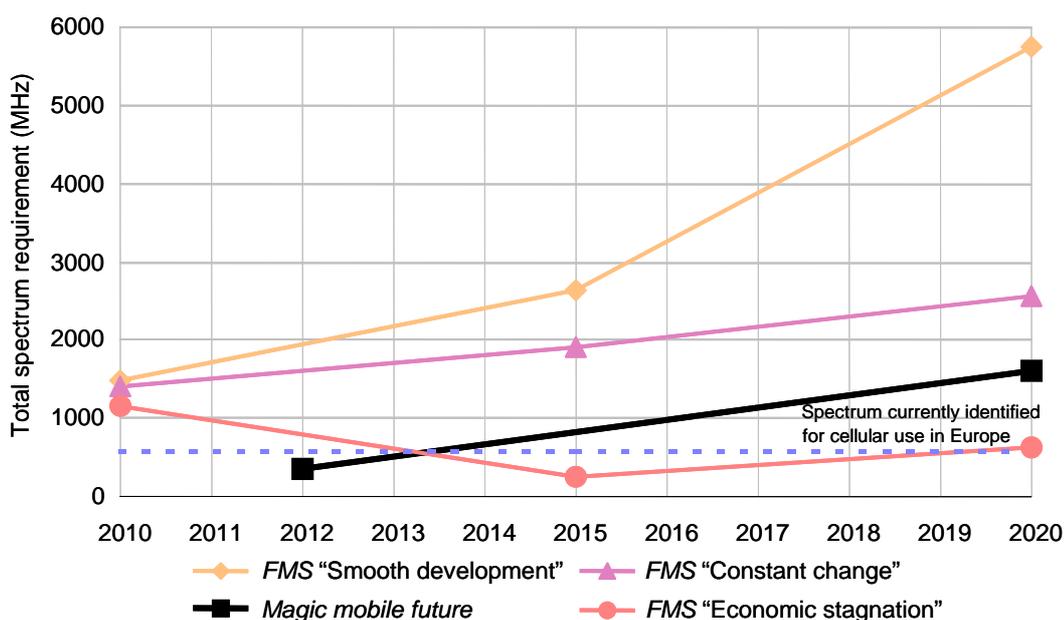
Using the traffic profiles extracted from the *Magic mobile future* and *FMS* reports, a cost model, as described in Section 3.1, has been used to calculate a series of spectrum-requirement forecasts. It should be remembered that the requirement forecasts are contingent on the input traffic forecasts that are being used. These forecasts are for a representative Western-European country. The outputs that are summarised in these sections are the total spectrum requirements in the country, including existing cellular spectrum.

We provide the forecast spectrum requirements for 2012 and 2020 for the *Magic mobile future* study, and for 2010, 2015 and 2020 for the *FMS* study. This is in line with those years for which actual traffic forecasts are provided in these respective reports.

In this chapter we present the results of our base case (Section 4.1) and of our scenarios (Section 4.2).

### 4.1 Base case results

Using the traffic profiles with our base-case assumptions, as summarised in Exhibit 3.5 above, the total spectrum forecasts obtained, including existing spectrum used for cellular services, are displayed in Exhibit 4.1.



**Exhibit 4.1:** Base-case spectrum requirements, in MHz<sup>9</sup> [Source: Analysys, *Magic mobile future*, FMS, 2005]

Exhibit 4.2 below shows the actual calculated values of spectrum requirements, in the years corresponding to those for which traffic forecasts are provided in the two reports.

Profile	2010	2012	2015	2020
<i>Magic mobile future</i>	n/a	360	n/a	1600
FMS "constant change"	1400	n/a	1920	2560
FMS "smooth development"	1480	n/a	2640	5760
FMS "economic stagnation"	1160	n/a	240	640

**Exhibit 4.2:** Base-case spectrum requirements, in MHz [Note: n/a means "not applicable"] [Source: Analysys, *Magic mobile future*, FMS, 2005]

As can be seen in Exhibit 4.2, the *FMS* scenario for "constant change" has significantly higher spectrum demand between 2010-2020 than the *Magic mobile future* study; this is due to the fact that the *FMS* study assumes higher growth in traffic earlier than the *Magic mobile future* study. The *FMS* scenario for "constant change" also yields a spectrum

<sup>9</sup> The spectrum currently identified for cellular use is 585MHz and includes the 900MHz and 1800MHz GSM bands, the DECT guard band, the 2GHz UMTS band and the 2.5GHz expansion band.

demand in 2020 that is over 50% greater than the *Magic mobile future* forecast. Meanwhile, using the “smooth development” scenario results in a forecast requirement in 2020 that is more than three times as large as the *Magic mobile future* forecast.

If the “economic stagnation” scenario is used, there is a substantial reduction in spectrum between 2010 and 2015, before increasing again by 2020 to 640MHz. This is because, after some sharp increases in traffic in the years before 2010, the volume then decreases due to the onset of a period of economic decline. However, note that, even though in this scenario we assume that operators continue to build out their networks and invest in more spectrally efficient technologies (e.g. systems beyond IMT-2000), this may not happen, in which case the spectrum demand in this scenario will be higher.

## 4.2 Other scenarios

In this section we present the results of each of our scenarios, which include: the proportion of traffic carried over IMT-2000 and systems beyond IMT-2000 networks; busy-hour assumptions; spectral efficiency improvements; and cost-saving threshold.

### *Variation of proportion of traffic carried over IMT-2000 and systems beyond IMT-2000 networks*

The final scenario taken with an input specific to the *FMS* study is the adjustment of traffic that is likely to be served via IMT-2000 or systems beyond IMT-2000, as explained in Annex A of this report. Exhibit 4.3 below shows that, by using the 50% adjustment, the spectrum demand in 2020 reaches a similar level to the *Magic mobile future* profile.

<i>Profile</i>	<i>Traffic adjustment</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
<i>Magic mobile future</i>	n/a	n/a	360	n/a	1600
FMS – “constant change”	50% in 2020	1400	N/a	1680	1920
FMS – “constant change”	70% in 2020	1640	N/a	1920	2560

**Exhibit 4.3:** *Spectrum requirements, in MHz, for scenarios around the traffic adjustment for the FMS study [Note: n/a means “not applicable” [Source: Analysys, Magic mobile future, FMS, 2005]*

### *Variation of busy hour*

The next sensitivity factor and the first across both reports is that of the busy-hour assumption. Using the value of 10% for the *Magic mobile future* profile produces a spectrum requirement of 1.9GHz in 2020. All the scenarios of the *Magic mobile future* profile still yield smaller requirements than those scenarios with the *FMS* base case, as demonstrated in Exhibit 4.4 below.

<i>Profile</i>	<i>Scenario</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
<i>Magic mobile future</i>	7.5%	n/a	360	n/a	1600
<i>Magic mobile future</i>	10%	n/a	520	n/a	1920
<i>FMS – “constant change”</i>	7.5%	1400	n/a	1920	2560
<i>FMS – “constant change”</i>	10%	1560	n/a	2160	2880

**Exhibit 4.4:** *Spectrum requirements, in MHz, for scenarios around the busy-hour assumption*  
 [Note: n/a means “not applicable”] [Source: Analysys, Magic Mobile Future, FMS]

### *Variation of spectral efficiency improvements*

Exhibit 4.5 below demonstrates the markedly different requirements arising from the scenarios for the improvements in spectrum efficiency. The low scenario assumes that the spectral efficiency for a system beyond IMT-2000 in 2020 will be five times that of UMTS today, while the medium and high scenario assume ten times and twenty times respectively. In both cases, the total spectrum requirement for the low scenario is more than double that of the high scenario.

<i>Profile</i>	<i>Scenario</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
<i>Magic mobile future</i>	Low	n/a	520	n/a	2880
<i>Magic mobile future</i>	Medium	n/a	360	n/a	1600
<i>Magic mobile future</i>	High	n/a	360	n/a	960
<i>FMS – “constant change”</i>	Low	1560	n/a	2640	3840
<i>FMS – “constant change”</i>	Medium	1400	n/a	1920	2560
<i>FMS – “constant change”</i>	High	1000	n/a	1200	1600

**Exhibit 4.5:** *Spectrum requirements, in MHz, for scenarios around the site capacity per carrier sector* [Note: n/a means “not applicable”] [Source: Analysys, Magic mobile future, FMS, 2005]

### *Variation of cost-saving threshold*

The final sensitivity run was on the cost-saving threshold, as defined in Section 3.3. As shown in Exhibit 4.6, the low scenario, with a threshold of EUR3 million per 2×5MHz unit of spectrum, yields a higher spectrum requirement by 2020, since the MNO requires a smaller reduction in network costs to see acquiring an extra carrier as worthwhile. In contrast, if the MNO only sees a cost of EUR15 million as a sufficient threshold, then using the forecasts of the two reports yields spectrum requirements in 2020 that are just over half of those in the low case.

<i>Profile</i>	<i>Scenario</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
<i>Magic mobile future</i>	Low	n/a	520	n/a	2240
<i>Magic mobile future</i>	Medium	n/a	360	n/a	1600
<i>Magic mobile future</i>	High	n/a	360	n/a	1280
<i>FMS – “constant change”</i>	Low	1560	n/a	2640	3200
<i>FMS – “constant change”</i>	Medium	1400	n/a	1920	2560
<i>FMS – “constant change”</i>	High	1000	n/a	1680	1920

**Exhibit 4.6:** *Spectrum requirements, in MHz, for scenarios around the spectrum opportunity cost [Note: n/a means “not applicable” [Source: Analysys, Magic mobile future, FMS, 2005]*

## 5 Conclusions

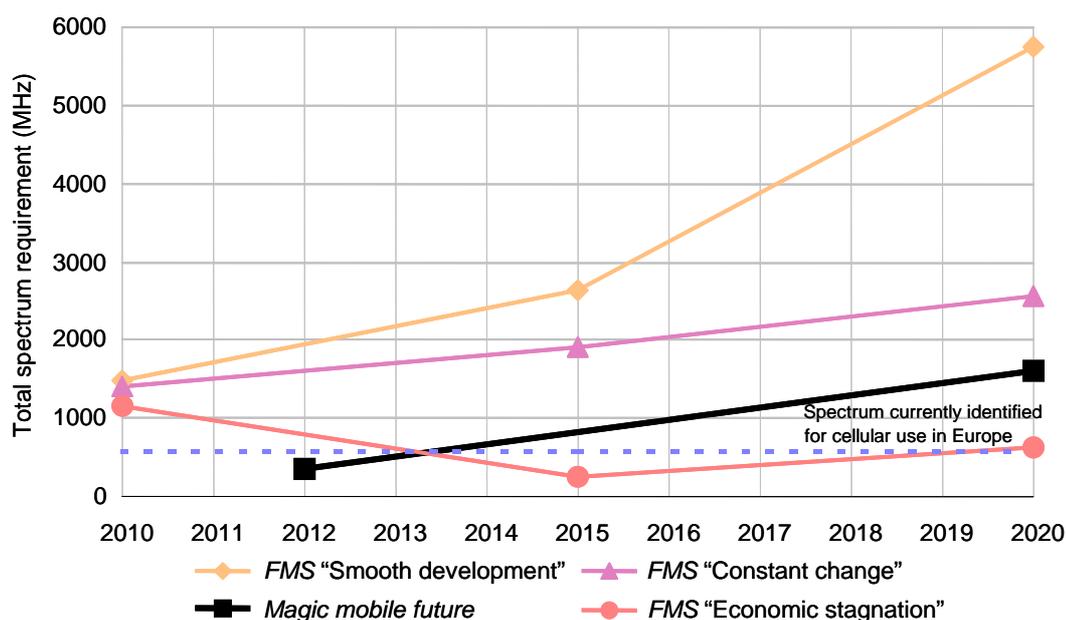
Both market studies used as inputs to these calculations predict significant growth in mobile traffic until year 2020. The overall results indicate that there will be a need for significantly more spectrum for cellular use than is currently identified for IMT-2000 and systems beyond IMT-2000.

Using the traffic profile forecasts in the *Magic mobile future* study, we calculate that, in our base case, the total demand for cellular spectrum will be 1.6GHz by 2020.

Using the traffic forecasts from the “constant change” scenario in the *FMS* study (the scenario that was used in CEPT’s contribution to the ITU-R as European Market Data), we calculate the total demand to be 2.6GHz by 2020.

The spectrum-requirement calculations based on the *FMS* study vary depending on the traffic scenarios chosen; the highest is the *FMS* “smooth development” scenario, which forecasts a total requirement of 5.8GHz in 2020. However, in practice, if traffic were to grow as sharply as forecast in this scenario, it is likely that this would necessitate many improvements in spectral efficiency than those used in this study, resulting in the actual total spectrum demand being lower than forecast under this scenario.

The spectrum forecasts are shown in Exhibit 5.1 below. The exhibit also shows the spectrum currently identified for cellular use – in many European countries there is currently around 395MHz of spectrum allocated for cellular use (in the 900MHz, 1800MHz, DECT guard and 2GHz bands), with the potential for an additional 190MHz in the 2.5GHz expansion band.



**Exhibit 5.1:** Spectrum requirements calculated using the spectrum forecasts<sup>10</sup> [Source: Analysys, *Magic mobile future*, FMS, 2005]

Our results also suggest that if traffic is to grow in line with the *Magic mobile future* forecast, the spectrum currently identified for cellular use is likely to be sufficient to meet demand beyond 2012. However, if traffic grows over the next five years at the rates suggested by the *FMS* report, then additional spectrum will be required before 2010. This is due to the fact that the *FMS* study assumes higher growth in traffic earlier than the *Magic mobile future* study.

Our scenarios have also illustrated a number of factors that may influence these spectrum requirements:

- **The busy-hour assumption** – If the busy-hour assumption is increased from 7.5% to 10%, then the spectrum requirements in 2020 rise from 1.6GHz to 1.9GHz (20%) when using the *Magic mobile future* traffic forecast, and increase from 2.6GHz to 2.9GHz (13%) when using the *FMS* “constant change” traffic forecast. Offering a service mix and pricing that results in a situation where the traffic is distributed as evenly as possible over the day would help to minimise the spectrum requirement.

<sup>10</sup> The spectrum currently identified for cellular use is 585MHz and includes the 900MHz and 1800MHz GSM bands, the DECT guard band, the 2GHz UMTS band and the 2.5GHz expansion band.

- **Improvement in spectral efficiency** – If the assumed improvement in spectral efficiency, which is already substantial, is assumed to be even greater (e.g. doubled by 2020), then the spectrum requirements in 2020 would be reduced. Consequently, the spectrum requirements fall from 1.6GHz to 1.0GHz (40%) when using the *Magic mobile future* traffic forecast, and from 2.6GHz to 1.6GHz (38%) when using the *FMS* “constant change” traffic forecast. This underlines the requirement for the development of new, more spectrum-efficient technologies.
- **Cost-saving threshold** – If the cost-saving threshold assumption is reduced from EUR7.5 million to EUR3 million, then the spectrum demand in 2020 increases from 1.6GHz to 2.2GHz (40%) when using the *Magic mobile future* traffic forecast, and from 2.6GHz to 3.2GHz (25%) when using the *FMS* “constant change” traffic forecast. Similarly, if this assumption is increased to EUR15 million, then the spectrum demand in 2020 decreases from 1.6GHz to 1.3GHz (20%) when using the *Magic mobile future* traffic forecasts, and from 2.6GHz to 1.9GHz (25%) when using the *FMS* “constant change” traffic forecast.
- **The traffic assumptions applied to the *FMS* study traffic forecasts** – If the proportion of overall mobile traffic that is assumed to be served via IMT-2000 or systems beyond IMT-2000 remains at 50% until 2020, then the cellular spectrum requirement in 2020 decreases from 2.6GHz to 1.9GHz (25%) by 2020. If this were to occur, more spectrum would need to be allocated to other technologies (e.g. WLANs).

It can be seen from all these results that the amount of spectrum currently allocated for cellular use in Europe is much lower than the future demand if the *Magic mobile future* and *FMS* traffic projections were realised.

Finally, it should be noted that this study is based on the *Magic mobile future* traffic forecasts for a *representative* Western-European country and on the *FMS* traffic forecast for “EU25 plus accessions”. Therefore, those Western-European countries with traffic demand and urban population density that are higher than average may require more spectrum than we have calculated in this study.

# **ANNEXES**

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A.2 Calculation of spectrum demand	A.5
Annex B: Bibliography	B.1

## Annex A: Detailed methodology

This annex provides further details on the methodology and calculations employed in our study. Section A.1 details how the traffic profiles from the *Magic mobile future* and *FMS* reports were transformed in order to be used in conjunction with our methodology. Section A.2 provides additional detail on the calculations used in the methodology to calculate spectrum demand.

### A.1 Transforming the traffic profiles into the required format

The forecasts in the two reports under consideration were not compatible with the methodology that was chosen by Analysys for use in this study. In order to calculate the spectrum requirements, we have translated the forecasts into the form of busy-hour traffic by geographical area based on population density called “geotypes.”

#### *Homogenisation of units*

The *FMS* report provides traffic profiles in units of daily minutes ( $\times 1000$ ) of 1Mbit/s, whilst the *Magic mobile future* traffic is in daily Tbytes. Both need conversion into daily Mbit/s.

#### *Representative population*

The *FMS* forecasts are for the population of the EU25, plus Bulgaria, Croatia and Romania, which total approximately 490 million people. Meanwhile, the *Magic mobile future* traffic is for a representative European country of 11 million people.

Our calculations are based on the demographics of a EU country with a population of approximately 60 million people. The traffic forecasts for each report have been scaled accordingly.

#### *Busy-hour assumptions*

The measure of traffic that is used in the calculations is busy-hour volume, as it is important, from an MNO's perspective, for quality of service (QoS) that the MNO's network can still function effectively in periods of peak traffic volume.

The *Magic mobile future* study uses a multiplying factor to provide traffic forecasts in this measure. The average factor used is 7.15%, which is lower than is typically used for cellular networks: 10–15%. However, since this study concerns traffic forecasts up until 2020, it may be appropriate to use a lower busy-hour assumption. This is due to the fact that in the future there will be more services that will generate traffic outside of the busy hour (e.g. M2M services), or services that are amenable to delays in arrival of traffic (e.g. email). The *FMS* study, meanwhile, only provides daily traffic rates.

In order to accommodate this difference, the traffic that we insert into the model is converted into the equivalent of daily traffic – in the case of the *Magic mobile future* forecast – and the busy-hour assumption is then incorporated inside the model. Two scenarios of 7.5% and 10% are used for this busy-hour factor, with 7.5% used in our base cases.

#### *Population density split*

The network topology is not uniform across the country due to the greater concentration of sites required in more urban regions. This is because of both the higher subscriber density and the reduction in a site's cell radius due to the greater concentration of buildings. For this reason, the country has been partitioned into eight classes called "geotypes", from dense urban to very remote, based on population density. The eighth geotype, highway, is included as highways often run through rural areas, yet they generate a significant amount of traffic. Hence, the highway geotype is assigned traffic but no area (this coverage element for these areas is included in the rural and remote geotypes). The traffic forecasts

from the two reports have then been split according to this partition and the network requirements have subsequently been calculated for each geotype. The classification used in this study has been based on the demographics of the UK: this is displayed in Exhibit A.1 below.

<i>Geotype</i>	<i>Lower bound pop. density (pop. per sq km)</i>	<i>Mean pop. density (pop. per sq km)</i>	<i>Area coverage (%)</i>	<i>Population coverage (%)</i>	<i>Traffic share (%)</i>	<i>Traffic share/pop. share</i>
Dense urban	7959	10 631	0	6	10	1.67
Urban	3119	4458	2	30	42	1.39
Semi-urban	782	1642	5	33	30	0.91
Semi-rural	112	265	19	21	11	0.50
Rural	47	73	23	7.00	2	0.29
Remote	25	35	14	2.00	0	0.22
Very remote	0	7	37	1.00	0	0.20
Highways	n/a	n/a	0.00	0.00	5	n/a

**Exhibit A.1:** *Land area and population geotypes [Note: n/a means not applicable] [Source: Analysys]*

#### *Other assumptions specific to the FMS study*

##### ► *Activity ratio*

As stated in Section 2.2, this factor was introduced into the report after the final results of the *FMS* report were officially published. The rationale behind its inclusion was to account for the periods of traffic inactivity from a subscriber when they are using the network. Our base cases for the *FMS* profiles include the activity ratio.

In the *FMS* report, the traffic volume was forecast using four baskets of services. Activity ratios have been applied to each basket in order to scale the volumes. The activity ratios that were used are displayed in Exhibit A.2 below.

<i>Basket of services</i>	<i>Activity ratio</i>
Communications	60%
Entertainment	70%
Lifestyle	20%
Business	20%

**Exhibit A.2:** Activity ratios applied to the FMS traffic profile

[Source: Analysys]

The appendices of the *FMS* study contain the traffic forecasts for each basket of services individually. Using this information, activity ratios for the total traffic volumes for each scenario in the report and for each of the forecast years – viz. 2010, 2015, 2020 – have been calculated. The values obtained are shown in Exhibit A.3 below.

<i>FMS scenario</i>	<i>2010</i>	<i>2015</i>	<i>2020</i>
Smooth	32%	46%	40%
Stagnation	31%	26%	22%
Change	29%	39%	28%

**Exhibit A.3:** Calculated values of activity ratios [Source: Analysys, *FMS* report appendices]

► *Non-IMT-2000/systems beyond IMT-2000 traffic*

The *FMS* forecasts include traffic that is likely to be served via technologies other than IMT-2000 or systems beyond IMT-2000 technologies. We multiply our traffic volumes by a factor to adjust for this. In our base case this is assumed to be 50% in 2005, rising to 70% in 2020; but we also have a scenario in which this figure remains at 50% until 2020.

Having made these reconciliations with the forecasts, the resulting raw traffic profiles that are used as inputs are displayed in Exhibit A.4 below.

<i>Profile (Mbit/s)</i>	<i>Busy-hour assumption</i>	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
<i>Magic mobile future</i>	7.5%	–	56 000	–	1 300 000
<i>FMS<sup>11</sup> – Change</i>	7.5%	150 000	–	1 000 000	2 500 000
<i>FMS – Stagnation</i>	7.5%	130 000	–	90 000	340 000
<i>FMS – Smooth</i>	7.5%	170 000	–	1 500 000	10 000 000

**Exhibit A.4:** Busy-hour traffic volumes (to 2s.f.) for each profile used in the model [Source: Analysys, *FMS*, *Magic mobile future*]

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The figures for all of the *FMS* scenarios include the activity ratio and a contraction factor of 70% to remove the superfluous traffic.

As can be seen in Exhibit A.4 above, each of the traffic profiles change over time in different ways. The *Magic mobile future* profile begins at a lower volume than any of the *FMS* cases. In fact, it is still lagging behind the 2010 *FMS* figures in 2012. The *FMS* “stagnation” case evolves differently to the others in that the volumes drop before showing recovery in the later years.

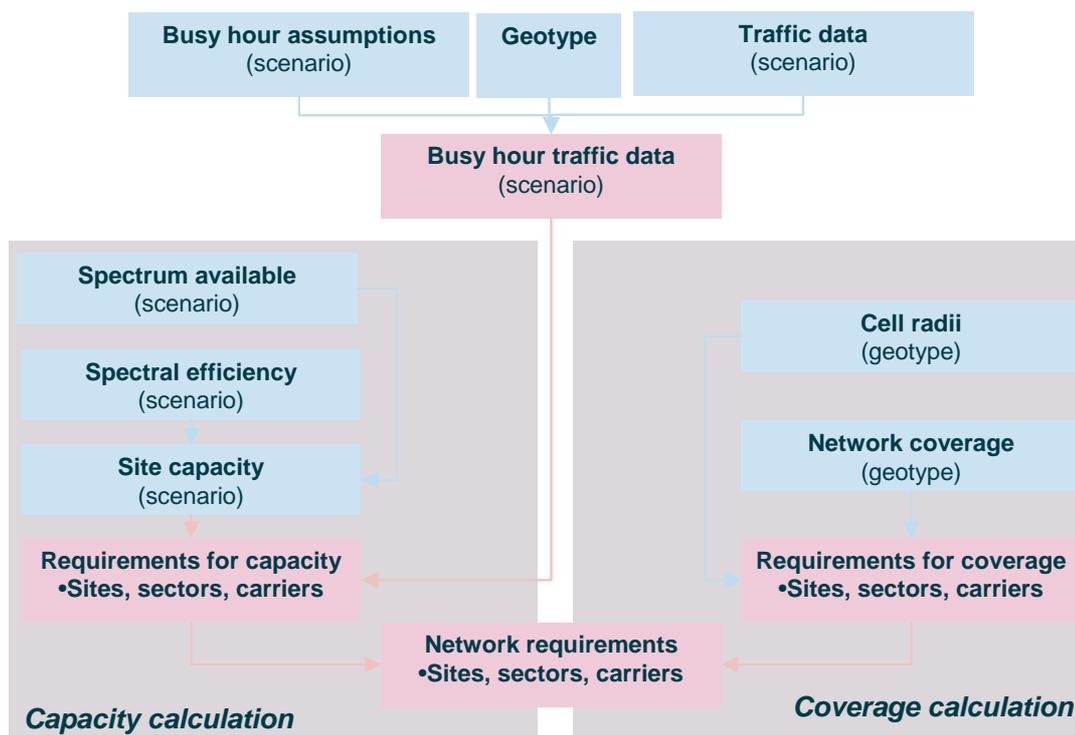
## **A.2 Calculation of spectrum demand**

We have modelled the spectrum demand for a representative EU country with a population of around 60 million. The model is taken from the perspective of a single MNO with a 25% market share and assumes that there are four operators in the market. The spectrum requirements, by year, of one MNO are calculated and the aggregate spectrum demand for all four operators is then obtained by multiplying the outputs by four.

Since we assume that the decision on the MNO’s spectrum requirements is based on the potential reduced cost of obtaining more spectrum, the emphasis of the cost model needs only be on those costs that change with the amount of spectrum. Additional spectrum enables the capacity of each site to be increased, so less sites overall will be needed to handle the capacity needs of the network. The sites needed for coverage will not change regardless of the amount of spectrum available.

### **A.2.1 Calculation of the number of sites**

Since the spectrum requirements are fundamentally driven by the number of sites in the network, this calculation is of particular importance. The methodology employed is displayed in Exhibit A.5 below.



**Exhibit A.5:** Network site forecasting methodology [Source: Analysys, 2005]

In order to have a functional network, there must be enough sites to not only provide coverage, but also to have sufficient capacity to cope with the traffic on the network. The country was firstly split into a number of geographical areas based on population density, named “geotypes”. For each year and across each geotype, the number of sites required for coverage and capacity has been calculated. Taking the maximum of these two values in each case gives the number of sites that need to be deployed in the particular geotype. The total number of sectors and carriers deployed in each site in the network are also calculated in the same way.

In order to calculate the number of sites needed for capacity, the capacity of a site is required. This is measured as the maximum busy-hour traffic that a site can handle per carrier per sector. This is calculated by the following equation:

$$\text{Site capacity per sector per carrier} = \text{useful channels} \times \text{full voice rate} \\ \times \text{actual carrier utilisation factor}^{12}$$

<sup>12</sup> This quantity accounts for practical factors, such as the uneven traffic across a geotype.

For UMTS technology, the assumptions that we use are displayed in Exhibit A.6 below:

<i>Quantity</i>	<i>Value</i>	<b>Exhibit A.6:</b> <i>Assumptions for the calculation of the UMTS base-station capacity [Source: Analysys, 2005]</i>
Carrier size	2×5MHz	
Useful channels (per sector)	43.3 <sup>13</sup> channels	
Full voice rate	0.013Mbit/s	
Actual channel utilisation factor – accounts for uneven traffic across a geotype	60%	

Under these assumptions, the capacity is calculated to be 0.34Mbit/s for UMTS in 2005. This capacity has been assumed to vary over the course of the modelling period, in order to account for future technological advances and increases in the carrier size. The size of each network carrier is also assumed to increase every two or three years, starting with 2×5MHz in 2005 and reaching 2×40MHz in 2020. The size of the carrier in each of the years relevant to this study is shown in Exhibit A.7 below.

	<i>2010</i>	<i>2012</i>	<i>2015</i>	<i>2020</i>
Carrier size (MHz)	2×10	2×20	2×30	2×40

**Exhibit A.7:** *Changes in the carrier size during the modelling period [Source: Analysys, 2005]*

The number of sites for capacity is then found by the following calculation:

$$\text{Number of sites for traffic} = \text{busy-hour traffic} / (\text{site capacity} \times \text{number of carriers per site})$$

## A.2.2 Key assumptions

The network cost<sup>14</sup> is the driver in the decision-making process regarding the number of carriers that an MNO will demand. As the number of sites changes with the amount of spectrum, there are several costs that will also vary. These elements have been included in our considerations and their key assumptions are explained in the following three sections.

<sup>13</sup> This is calculated by starting with 80 channels, scaling by 30% for soft handover and then incorporating a 1% blocking probability.

<sup>14</sup> By network cost we mean the sum of the capex and the opex for the year in question.

The first section discusses the general assumptions made about the network; the second section discusses the capex assumptions; whereas the third and final section describes the assumptions related to opex.

### ***Network assumptions***

*Node B and base-station sites* We assume that the number of stations in each geotype does not decrease from one year to the next.

As has been stated, GSM sites have not been included in the modelling calculation: only the UMTS and beyond IMT-2000 networks are considered. Therefore, our model does not assume that UMTS/beyond IMT-2000 network sites are shared with GSM.

*Backhaul* We assume that no leased-line backhaul is used in the network: only microwave backhaul is deployed. The capacities assumed to be available are 2, 8, 16, 32, 64, 128, 256 and 512Mbit/s.

The average site capacity is used to calculate the number of links required by geotype. The total number of each capacity of link is then calculated before, finally, the values are scaled by 1.3. This accounts for the topology of the backhaul network since, on average, each site will have more than one backhaul link.

*Radio network controllers (RNCs)* We assume that the number of RNCs required is driven by the number of carriers deployed per site.

We also assume that RNC technology improves over the modelling period, with an RNC needed for every 150 carriers deployed in sites in 2005, but only for every 322 carriers deployed in sites by 2020. This assumption also incorporates the increasing size of the carriers, as detailed above in Exhibit A.7.

*Network assumptions for 2005* We have assumed that there are 7460 standalone base-station sites in the network. We also assume that the network is equipped with 187 RNCs.

### ***Capital expenditure***

<i>Node B and base-station sites</i>	The associated costs for each incremental site has been benchmarked on industry data. The cost of a Node B is assumed to be EUR50 000 in 2005, with an annual decrease of 7%. The cost of acquisition per site is assumed to be EUR80 000 in 2005, with an annual increase of 2.5%.
<i>1×1×1 carriers</i>	The cost of each 1×1×1 carrier is assumed to be EUR12 000 in 2005, with an annual decrease of 7%.
<i>Backhaul</i>	<p>The capex costs are split into those for completely new links and upgraded links. In both cases, we assume that prices decrease by 8% annually:</p> <ul style="list-style-type: none"> <li>• <b>new links</b> – we assume that a 2Mbit/s link costs EUR10 000, with each successive higher level of capacity costing 1.1 times the previous capacity. We also assume that these prices drop by 8% per annum</li> <li>• <b>upgraded links</b> – we assume that each successive upgrade increases in price by EUR1500, with an upgrade from a 2Mbit/s link to an 8Mbit/s link costing EUR1500. An upgrade of several capacities is assumed to be 80% of the sum of the equivalent individual upgrades. All the upgrading prices are assumed to decrease by 8% per annum.</li> </ul>
<i>RNCs</i>	The cost of an RNC is assumed to be EUR500 000 in 2005, which experiences a decrease of 7% per annum.

### ***Operating expenditure***

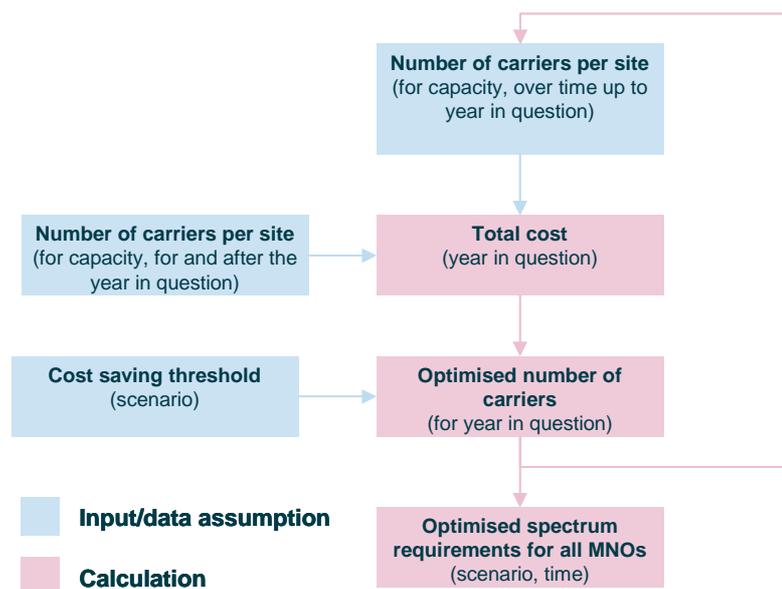
<i>Node B and base-station sites</i>	The site rental is assumed to be EUR12 000 per site per year in 2005, with an annual growth of 2.5% per annum.
<i>Backhaul</i>	The operating costs are considered per incremental link in the network. A 2Mbit/s link is assumed to cost EUR1300 per year, with each successive capacity costing 1.5 times more. These prices are assumed to increase by 2.5% per annum.

*Network maintenance* The network maintenance cost for any particular year has been taken to be 3% of the cumulative capex from 2006 up to and including that year.

Those costs which are largely independent of the MNO’s spectrum allocation have not been accounted for in this study. These include: the costs of the core network infrastructure (MSC, GGSN, SGSN, VMS, MGW, etc.); replacement capex; interconnect costs; roaming costs; marketing expenditure; staff costs, etc. In particular, replacement capex is not included since this can be seen as a sunk cost with regard to any particular year under consideration.

### A.2.3 Calculation of spectrum demand

The desired output of the model is to identify the spectrum requirements of an MNO, year by year, so that the cost of its network can be minimised. The structure of the procedure used is displayed below in Exhibit A.8.



**Exhibit A.8:** Optimisation of the spectrum requirements for the MNO [Source: Analysys, 2005]

For each year, the total capex and opex is calculated for a range of carriers available to the operator. If the cost saving is greater than the cost-saving threshold, then it is assumed that the operator would demand this additional spectrum.

## Annex B: Bibliography

This annex provides details and sources for the documents that have been used in the preparation of this study:

- UMTS Forum (2005), *Magic mobile future 2010-2020*. Available at [www.umts-forum.org](http://www.umts-forum.org).
- European Commission Directorate, General Joint Research Centre/Institute for Prospective Technological Studies (2005), *The demand for future mobile communications markets and services in Europe (FMS study)*. Available at [www.jrc.es](http://www.jrc.es).
- ITU-R Radiocommunications Study Groups (2005), *Methodology for calculation of spectrum requirements for the future development of terrestrial component of IMT-2000 and systems beyond IMT-2000 (Document 8/113-E)*. Available at [www.itu.int](http://www.itu.int).
- Analysys (2005), *Spectrum demand for non-governmental services 2005-2025*. Available at [www.spectrumentaudit.org.uk](http://www.spectrumentaudit.org.uk) or [www.analysys.com](http://www.analysys.com)