REPORT ITU-R M.2023

SPECTRUM REQUIREMENTS FOR INTERNATIONAL MOBILE TELECOMUNICATIONS-2000 (IMT-2000)

(2000)

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1 Summary

IMT-2000 defines 3rd generation mobile systems which are scheduled to start service around the year 2000 subject to market considerations. They will provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks such as PSTN and ISDN, and to other services which are specific to mobile users.

A range of mobile terminal types is encompassed, linking to terrestrial and/or satellite-based networks; these terminals may be designed for mobile or fixed use.

Key features of IMT-2000 are:

– high degree of commonality of design worldwide;

– compatibility of services within IMT-2000 and with the fixed networks;

– high quality;

– small terminals for worldwide use;

– worldwide roaming capability;

– capability for multimedia applications, and a wide range of services and terminals.

This Report is useful for Administrations when considering IMT-2000 spectrum requirements. It should be used in preparation for WRC-2000, including development of draft text for the CPM Report.

2 Background

2.1 Administrations may consider the following factors that are relevant to IMT-2000 spectrum:

a) that IMT-2000 systems are defined by a set of interdependent ITU Recommendations and Reports of which this Report is a member;

b) that RR No. S5.388 indicates that "the bands 1 885-2 025 MHz and 2 110-2 200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement International Mobile Telecommunications-2000 (IMT-2000). Such use does not preclude the use of these bands by other services to which these bands are allocated. The band should be made available for IMT-2000 in accordance with Resolution 212 (Rev.WRC-97)";

c) that the RR also allocate within these bands the portions 1 980-2 010 MHz and 2 170-2 200 MHz to the MSS on a worldwide basis, potentially for use by the satellite component of IMT-2000, under the provisions of RR No. S5.389A;

d) that the RR also allocate 2 010-2 025 MHz and 2 160-2 170 MHz in Region 2 to the MSS under the provisions of RR Nos. S5.389C, S5.389D and S5.389E and Resolution 212 (Rev.WRC-97);

e) that portions of the bands identified for the implementation of IMT-2000 (1 885-2 025 MHz and 2 110-2 200 MHz) are used by existing terrestrial fixed services under current allocations;

f) that the initial implementations of IMT-2000 are expected to commence around the year 2000 subject to market considerations;

g) that IMT-2000 systems will provide different categories of services in various environments;

h) that the bands identified in § 2.1 b) are shared with other systems of the mobile, fixed and mobile-satellite services and the band 2 110-2 120 MHz is shared with the space research service, and that many of these systems are in use now;

j) that these bands are used differently in various countries, even within the same Region;

k) that all forecasts show that there will be a growth in the number of mobile subscribers in the future;

l) that the traffic and service mix carried by IMT-2000 systems may vary from country to country, and also within countries; in some parts of the world additional spectrum may be required whilst in other parts of the world the frequency bands identified in § 2.1 b), c), and d) could be adequate to meet IMT-2000 services present and future demands;

m) that the amount of traffic handled by mobile systems as well as the number and diversity of services will continue to grow;

n) that there is a need to support the operation of IMT-2000 terminals in different regulatory environments;

o) that the various radio access technologies that may be appropriate for IMT-2000 may have different channel bandwidth requirements, different capability, and hence varying impact on the basic frequency usage possibilities;

p) that selection of a worldwide frequency band will facilitate the use of global roaming;

q) that future systems may include the use of a range of cell types from small indoor cells to large satellite cells in a given location;

r) that IMT-2000 will offer higher data rate services than earlier systems in order to meet increasing customer demands, and this could create a demand for additional spectrum beyond that earlier estimated;

s) that the spectrum requirement calculation will necessitate assumptions on typical IMT-2000 deployment scenarios; that efficiency of spectrum use requires consideration of the balances between IMT-2000 system costs and bandwidth needed.

2.2 Administrations may further consider, relative to the terrestrial component:

a) that in some countries, within the lower part of the 1 885-2 025 MHz IMT-2000 band, digital enhanced cordless telecommunication (DECT) operates at 1 880-1 900 MHz, and personal handy phone system (PHS) at 1 893.5-1 919.6 MHz. Also, in some countries personal communication services (PCS) systems based on North American standards employ 80 MHz duplex separation within the band 1 850-1 990 MHz;

b) that administrations may choose to permit operators to use frequency bands currently allocated to pre-IMT-2000 mobile service for IMT-2000 usage as a strategy for the evolution from 2nd generation wireless systems to 3rd generation wireless systems having IMT-2000 capabilities;

c) that spectrum requirements for the terrestrial component of IMT-2000 were estimated in Report ITU-R M.1153 prior to WARC-92 at which time the primary wireless service emphasis was on voice services whereas IMT-2000 systems will provide a variety of wideband data and multimedia services in addition to voice services. Report ITU-R M.1153 is now documented in Recommendation ITU-R M.687;

d) that the methodology described in Recommendation ITU-R M.1390 – Methodology for the calculation of IMT-2000 terrestrial spectrum requirements has been used to calculate the spectrum requirement for the terrestrial component of IMT-2000.

2.3 Administrations may further consider, relative to the satellite component:

a) that the need for additional spectrum for the MSS in the 1-3 GHz range has been stated in the CPM Reports to the last two WRCs. The CPM Report to WRC-95 indicated that a total allocation of between 2×75 MHz and 2×150 MHz would be required by 2005 (Part A.2, 3 to Chapter 2);

b) that the CPM Report to WRC-97 indicated that 2 x 250 MHz would be necessary by 2010;

c) that currently the RR allocate about 2×115 MHz to the MSS in the 1-3 GHz range, with some regional variations;

d) that most of these bands are used by other services in most countries, substantially reducing the actual availability of those bands for the MSS, and in many countries they are not available for MSS at all;

e) that a large number of satellite systems have been advanced published by the ITU for the MSS frequency bands between 1-3 GHz (as of November 1998). Some of these systems have been filed in more than one band;

f) that the bands 1 525-1 559/1 626.5-1 660.5 MHz and 1 610-1 626.5/2 483.5-2 500 MHz are rapidly becoming congested due to an increasing number of operational and planned MSS systems with growing spectrum requirements, which has become apparent in the annual multilateral coordination meetings in all Regions with respect to the first pair of bands;

g) that as other MSS bands in 1-3 GHz become available, these bands may also become congested when the satellite networks published are brought into operation;

h) that the satellite forecasts have been based on extensive primary and secondary research conducted globally. One major global mobile satellite company's forecast (Appendix 3 to Annex 1) is based on extensive market analysis, including primary market research which involved screening over 200 000 persons and interviewing more than 23 300 individuals from 42 countries and 3 000 corporations with remote operations;

j) that another major global mobile satellite company's forecast (Appendix 5 to Annex 1) is based on detailed user and potential user surveys in over 15 countries in the world covering over 1 000 companies and individuals, building on forecast and user profile information obtained during almost 20 years of operation;

k) that the methodology described in Recommendation ITU-R M.1391 – Methodology for the calculation of IMT-2000 satellite spectrum requirements, has been used to calculate the spectrum requirement for the satellite component of IMT-2000.

3 Conclusions

The conclusions of this Report are:

a) that the market forecast data and technical parameter values of Annex 1 and its Appendices should be used by administrations for IMT-2000 spectrum requirements;

b) that there is a forecasted need for *160 MHz* of additional spectrum for terrestrial IMT-2000, beyond the terrestrial IMT-2000 spectrum already identified in RR No. S5.388 and beyond the spectrum used in the various Regions for lst and 2nd generation mobile systems. This forecast should be considered by administrations in addressing IMT-2000 spectrum requirements. A summary is provided in Table 1;

c) that the forecasted satellite spectrum requirement for the years 2005 and 2010, as provided in Table 2, should be considered by administrations in addressing IMT-2000 spectrum requirements.

TABLE 1

Summary of global mobile terrestrial spectrum requirement including the IMT-2000 terrestrial component

Region	Total forecasted terrestrial mobile spectrum requirement for the year 2010 (MHz)(1)	Identified total terrestrial mobile spectrum (including RR No. S5.388 IMT-2000 spectrum) (MHz)	Forecasted additional IMT-2000 terrestrial component spectrum requirement for the year 2010 (MHz)
Region 1	555	395	160
Region 2	390	230	160
Region 3	480	320	160

(1) The figures represent the requirement in those geographical areas where the traffic is the highest.

The identified total terrestrial mobile spectrum consists of the spectrum already identified in RR No. S5.388 for terrestrial IMT-2000 and also the spectrum used for lst and 2nd generation mobile systems. The resultant additional IMT-2000 terrestrial component spectrum required is also presented in Table 1. It is recognized that the existing identified terrestrial spectrum may vary between countries within a Region. Additional information is provided in Annex 1, § 2.4.

TABLE 2

Summary of global mobile satellite spectrum requirements, including IMT-2000 satellite component (MHz)

Year	2005	2010
IMT-2000 (satellite component)	$2 \times 31,5$	2×67
Total MSS (including IMT-2000 satellite component)	2×123	2×145

NOTE 1 – The figures in Table 2 represent the requirement in those geographical areas where the traffic is the highest. The basis for these satellite requirements are the forecasts detailed in Annex 1, § 3.

In the various regions, consideration must be given to the existing spectrum assigned for pre-IMT-2000 MSS services. Because the total MSS satellite calculation includes both pre-IMT-2000 and IMT-2000 services, a subtraction of the existing satellite spectrum allocated to the pre-IMT-2000 services must be performed to determine the additional satellite spectrum required for the IMT-2000 satellite component in the years 2005 and 2010. This subtraction has not been done in this Report, due to the variation across administrations of the spectrum allocated to pre-IMT-2000 satellite services.

ANNEX 1

1 Introduction and scope

Spectrum requirements for the terrestrial component of IMT-2000 were estimated prior to WARC-92 in the ex-CCIR Report to WARC-92. These spectrum calculations are now documented in Recommendation ITU-R M.687. Speech services were considered to be the major source of traffic at the time. As technological advancements carry us toward the 21st century, customers will demand more and more capabilities from wireless services. Future wireless services must support not only speech but also a rich range of new services that will serve a wide range of applications. Bearer services supporting applications such as multimedia, Internet access, imaging and videoconferencing will be needed in 3rd generation wireless system. In response to these new applications, IMT-2000 will support high rate data services.

The provision of the new services described in Recommendation. ITU-R M.816 – Framework for services supported by International Mobile Telecommunications-2000 (IMT-2000) has an impact on the spectrum requirements of IMT-2000 systems. Therefore it is necessary to revisit the original spectrum estimations in Report ITU-R M.1153 and examine:

– if the original spectrum estimates are still adequate; and

– if not, how much additional spectrum is needed.

1.1 Scope

This Report:

a) refers to the methodologies used in calculating spectrum requirements for both terrestrial and satellite mobile services;

b) describes the forecast demand estimates for such services;

c) provides the values used for the parameters in the spectrum calculation equations;

d) provides the numerical results of the application of the spectrum calculation methodologies for terrestrial and satellite mobile services; and

e) determines the amount of spectrum needed to support IMT-2000 services by both the terrestrial and satellite components of IMT-2000.

It is recognized that the requirements expressed in this Report will be considered in preparation for WRC-2000. This Report does not include methods to meet these requirements, discussion of the needs of other services, analysis of available spectrum, techniques required to facilitate sharing between IMT-2000 and other services, and other factors related to spectrum.

2 Terrestrial component of IMT-2000

The definitions of the IMT-2000 terrestrial services are provided in § 2.1. These are bearer services as opposed to application services which are defined in Recommendation ITU-R M.816. Sections 2.2 and 2.3 respectively provide descriptions of the market and technical parameter values for the services that are described in § 2.1. Appendix 1 to Annex 1 provides additional detailed discussion of the values that are considered appropriate for calculation of commercial wireless traffic. Appendix 2 to Annex 1 is the detailed terrestrial component spectrum calculations for Regions 1, 2, and 3.

2.1 Service definitions for the terrestrial component of IMT-2000

Service definitions for IMT-2000 are provided in Recommendation ITU-R M.816. The service definitions used in the terrestrial spectrum calculations which are defined below are consistent with the Recommendation ITU-R M.816

definitions. Section 7 of Recommendation ITU-R M.816 considers IMT-2000 application services whilst Recommendation ITU-R M.1390 considers bearer services. The bearer services used in the spectrum calculations can be categorized as follows:

– speech (S);
– simple messaging (SM);
– switched data (SD);
– asymmetrical multimedia services;
– symmetrical multimedia services.

Additional detail is provided in Appendix 1 to Annex 1.

2.2 Market considerations for terrestrial component

Penetration rates are defined as the ratio of terrestrial land mobile subscribers for each service, and the total number of persons present in a representative area under consideration (e.g. a cell area of 1 km^2 or equivalent). In marketing terms, this is referred to as the demand estimate which is defined as the percentage of total population subscribing to a specific service. Individuals may have multiple subscriptions to mobile services and individuals may use more than one service.

The market figures detailed in Appendix 1 to Annex 1 are used to estimate spectrum requirements for the year 2010 and administrations may wish to consider these figures in their spectrum assessments. These market figures for each of the representative service types are presented by environment and are expressed as penetration rates. Industry analyses in Regions 1, 2, and 3 that address IMT-2000 market forecasts have been submitted in 1998 to ITU-R by several administrations. The analyses were developed from market research performed by several industry associations in conjunction with well-known analysis firms. After extensive discussion among the representatives from the three Regions it was possible to develop a unified global IMT-2000 forecast. This unified forecast is a reasonable amalgamation of each individual region and truly indicates the global nature of IMT-2000 while retaining closeness to the views expressing individual regional assessments of future IMT-2000 markets. The forecast is considered to be the best available information on future demand for commercial wireless services.

2.3 Technical parameters for terrestrial component

The parameters used in the spectrum calculation methodology defined in Recommendation ITU-R M.1390, are the following:

1	Population density	7	Quality of service
2	Cell area	8	Number of cells per group
3	Penetration rate	9	Service channel bit rate
4	Busy hour call attempt (BHCA)	10	Net system capability
5	Call duration	11	Alpha factor
6	Activity factor	12	Beta factor

All other quantities in the methodology are calculated values which are obtained using the equations specified in § 2 and 3 of Recommendation ITU-R M.1390 and appropriate values for the input parameters listed above. Further information may be found in Appendix 1 to Annex 1.

2.4 IMT-2000 terrestrial component spectrum requirement

Appendix 2 to Annex 1 contains the outputs from spreadsheets for the detailed calculations that are representative of Regions 1, 2, and 3 for the terrestrial spectrum requirements for IMT-2000 in geographical areas where traffic is the highest. The spreadsheets use the methodology of Recommendation ITU-R M.1390 and the input parameter values provided in Appendix 1 to Annex 1.

Table 3 provides a summary of year 2010 spectrum requirements for services that are considered to be current wireless services and year 2010 spectrum requirements for new 3rd generation services to be provided by IMT-2000 systems. Current services include S, SM, and SD services. New IMT-2000 services include medium multimedia (MMM), high multimedia (HMM), and highly interactive multimedia (HIMM).

TABLE 3

Global mobile terrestrial spectrum requirements by service classes

Region	1G and 2G services (S, SM and SD) (MHz)	3G new services (MMM, HMM, HIMM) (MHz)	Total spectrum requirements (MHz)
Region 1	269	286	555
Region 2	174	216	390
Region 3	232	248	480

NOTE 1 – It is recognized that 3G services includes the 1G and 2G services, but this Table is constructed to delineate the higher data rate 3G services spectrum requirement from the speech and lower data rate services spectrum requirement.

For example, in examining the Region 2 totals, it is observed that the current services (S, SM, and SD) require a total of approximately 174 MHz for the year 2010. In some administrations in Region 2, the current allocation for these services is approximately 190 MHz. Therefore, the wireless industry for these administrations in Region 2 may be able to accommodate future growth of existing services with the current allocation assuming the air interface is changed to incorporate the more efficient and higher capacity IMT-2000 technology. This improvement in system efficiency is assumed in the value used for the net system capability parameter in Appendix 1 to Annex 1. Table 3 also shows that the spectrum requirement for these same administrations in Region 2 for new higher data rate services (MMM, HMM, and HIMM) totals approximately 216 MHz. It is clear from Table 3 that the additional terrestrial spectrum requirements are driven by the new wideband services, namely, HIMM, HMM, and MMM.

Table 4 provides a summary of estimated terrestrial IMT-2000 spectrum requirements for each of the three ITU Regions.

TABLE 4

Summary of global mobile terrestrial spectrum requirement including the IMT-2000 terrestrial component

Region	Forecasted total terrestrial mobile spectrum requirement (2010) (MHz)	Identified total terrestrial mobile spectrum (including RR No. S5.388 IMT-2000 spectrum) (MHz)	Forecasted additional IMT-2000 terrestrial component spectrum requirement (2010) (MHz)
Region 1	555	395	160
Region 2	390	230	160
Region 3	480	320	160

In the various Regions, consideration must be given to existing spectrum assigned for pre-IMT-2000 services. Because the total terrestrial calculation includes both pre-IMT-2000 and IMT-2000 services, a subtraction of existing identified terrestrial spectrum must be performed to determine the additional IMT-2000 terrestrial component spectrum in the year 2010. The identified total terrestrial mobile spectrum consists of the spectrum already identified in RR No. S5.388 for terrestrial IMT-2000 and also the spectrum used for lst and 2nd generation mobile systems as detailed below. The resultant additional IMT-2000 terrestrial component spectrum required is also presented in Table 4. It is recognized that the existing identified terrestrial spectrum may vary between countries within a Region.

For *Region 1* the existing spectrum of 395 MHz is determined as:

– 70 MHz assigned for GSM900 and its extension bands (E-GSM), (880-915/925-960 MHz);

– 150 MHz assigned for GSM1800, (1 710-1 785/1 805-1 880 MHz);

– 20 MHz assigned for DECT (1 880-1 900 MHz); and

– 155 MHz of the 230 MHz of spectrum which is identified in RR No. S5.388 for IMT-2000.

This amount is valid for most European Union and European Conference of Postal and Telecommunication Administrations (CEPT) countries, although there are some countries in Region 1 with different amounts of existing spectrum.

For *Region 2* the existing spectrum of 230 MHz is determined as:

– 190 MHz for cellular and PCS and similar services (824-849/869-894, 1 850-1 990 MHz);

– 40 MHz of the 230 MHz of spectrum which is identified in RR No. S5.388 for IMT-2000.

This amount is valid for most Inter-American Telecommunications Commission (CITEL) countries, although there are some countries in Region 2 with different amounts of existing spectrum.

For *Region 3* the existing spectrum of 320 MHz is determined as:

– 150 MHz for cellular, (includes portions of 810-958 MHz and portions of 1 429-1 501 MHz);

– 26 MHz for PHS (1 893.5-1 919.6 MHz); and

– 144 MHz of the 230 MHz of spectrum which is identified in RR No. S5.388 for IMT-2000.

This amount is valid for Japan, although there are some countries in Region 3 with different amounts of existing spectrum.

3 Satellite component of IMT-2000

3.1 Services and data rates

IMT-2000 MSS will largely be an extension of terrestrial wireless 3G services and capabilities, with certain modifications designed to meet the specific needs of the MSS user. The services for MSS applications are focused on the mobile user, employing handsets or handset-laptop combinations. Fixed alternatives, such as those anticipated by new non-GSO FSS operators, do not meet the needs of the mobile user. As is the case for the terrestrial component of IMT-2000, the service descriptions for the Satellite Component are consistent with the concepts expressed in Recommendation ITU-R M.816. See also Recommendation ITU-R M.1167 – Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000).

There are four broad categories of MSS in the IMT-2000 offering, ranging in transmission speed from 4 kbit/s to 384 kbit/s - voice; messaging and low-speed data; asymmetric multimedia; and interactive multimedia services.

Multimedia data at 2 Mbit/s is excluded from the general discussion of IMT-2000 MSS, as it is not expected to be provided as a mobile service offering by MSS operators. Table 5 shows the data rates for the satellite service types and the similarity of MSS and terrestrial service offerings for IMT-2000. This comparison shows synergy between the two components of IMT-2000. Further descriptions of these services are provided in Appendices 3 and 5 to Annex 1.

TABLE 5

Satellite service types and associated data rates used in the market research studies

Satellite service type	Satellite data rate (kbit/s)	Closest corresponding terrestrial service type
Voice	4-16	S
Messaging and low speed data	9.6-16	SM + SD
Asymmetric multimedia	Up to 144	MMM
Interactive multimedia	Up to 384	HIMM

3.2 Market considerations for satellite component

Market figures for the satellite component are derived from market research from two major global satellite organizations. Traffic forecasts for the satellite component of IMT-2000 for the years 2005 and 2010 have been provided from two sources:

– one from the United States of America; and

– one from Inmarsat.

The forecasts can be found in detail in Appendices 3 and 5 to Annex 1. Although the forecasts for the satellite component have shown significant variations depending on the geographic area, both forecasts show a significant demand for satellite IMT-2000 services. However, there are differences between the two, which is to be expected when forecasting such a long period into the future, and the differences are easily attributable to differences in the underlying focus of each company's research and methodology.

Investigation was undertaken to identify whether the two submissions could be merged or combined into a single forecast. However, given that each forecast presents its own perspective on the evolution of market demand, it was decided that they should remain separate. A summary of the forecasts and a discussion of their similarities and differences are given below.

Similarities between the forecasts:

– both focus exclusively on mobile applications (none of the services identified are for fixed terminals);

– both focus on services that have been identified specifically as IMT-2000 types of applications (voice and multimedia services);

– both focus on forecast usage in 2005 and 2010; and

– both forecasts include frequent users (i.e. those people who require and use satellite communications as a key part of their day-to-day communications needs) and infrequent users (i.e. predominantly terrestrial wireless IMT-2000 subscribers who rely on satellite communications when they roam outside of terrestrial wireless coverage).

Differences between the forecasts:

– while both forecasts include frequent and infrequent users, the frequent portion of the United States of America forecast is reported as very conservative. The Inmarsat forecast, on the other hand, provides more information on the frequent user of multimedia services; and

– while both forecasts use primary market research as a basis for their projections, the research has been focused on different areas. The Inmarsat primary research focused on frequent users (and usage) of multimedia services, whereas the United States of America primary research focused on global subscribers and voice/data usage.

Thus each forecast uses different techniques and assumptions to arrive at the final forecasts, and both will be used to project spectrum requirements.

3.3 Satellite spectrum calculations

The calculation of spectrum requirements based on the United States of America's forecasts is shown in Appendix 4 to Annex 1. Using the Inmarsat forecasts as a basis, the calculation of spectrum requirements is shown in Appendix 6 to Annex 1. Both of these calculations are carried out using the methodology of Recommendation ITU-R M.1391 and are based on satellite traffic for geographic areas where traffic is highest. Summaries of the results of the calculations in Appendices 4 and 6 to Annex 1 are given in Tables 6 and 7 respectively.

TABLE 6

Summary of spectrum needed to support IMT-2000 MSS requirements based on the United States of America's forecasts

Region(1)	2005 Uplink (MHz)	2005 Downlink (MHz)	2005 Total (MHz)	2010 Uplink (MHz)	2010 Downlink (MHz)	2010 Total (MHz)
Region 1	33	33	66	68	68	136
Region 2	19	19	38	39	39	78
Region 3	15	15	30	32	32	64

(1) These results are based on a global market forecast.

TABLE 7

Summary of estimated satellite IMT-2000/MSS spectrum requirements based on Inmarsat forecasts (MHz per direction of transmission)

Row	Traffic type	Year	
		2005	2010
1	Non IMT-2000(1)		
2	– Non-multimedia	93	79
3	IMT-2000		
4	– Non-multimedia	3	11
5	– Multimedia	27	55
6	Total IMT-2000	30	66
7	Total MSS	123	145

(1) It is assumed that all multimedia traffic will be IMT-2000 compatible. The total MSS spectrum in row 7 is the non-IMT-2000 (row 2) plus the total IMT-2000 (row 6).

3.4 Discussion and conclusions

The results shown in Tables 6 and 7 and in more detail in Appendices 4 and 6 to Annex 1, are based on the best information available and are considered to be representative for IMT-2000. They imply a significant need for additional spectrum for the services delivered by the satellite component of IMT-2000. The need for additional spectrum to support IMT-2000 MSS systems must be viewed in the context of the spectrum currently available, and used, on a global basis for MSS between 1 and 3 GHz. Because of the time required for build-out of MSS systems (i.e. development, permitting, construction, launch, and commissioning, etc. on a global basis) two time-frames of demand are presented, 2005 and 2010. This provides an indicator of the rate of demand for satellite services over time.

The Inmarsat forecasts will be adopted for total MSS demand estimates, as the United States of America's study does not cover total MSS. Both studies have assessed the requirements for satellite IMT-2000. The spectrum requirements presented are those that accommodate the largest regional requirements. Thus for the year 2010, the United States of America's forecasts project a demand of 2×68 MHz, while the Inmarsat forecasts project a demand of 2×66 MHz. Because the two results are so similar, an average of the two forecasts (2×67 MHz) will therefore be used for the satellite component of IMT-2000 for 2010, and similarly 2×31.5 MHz for 2005.

APPENDIX 1

TO ANNEX 1

Discussion about selection of parameter values for terrestrial spectrum calculations

Terrestrial spectrum calculation parameters defined in Recommendation ITU-R M.1390

The parameters used in the spectrum calculation methodology defined in Recommendation ITU-R M.1390, are the following:

TABLE 8

Summary of parameters

1	Population density	7	Quality of service
2	Cell area	8	Number of cells per group
3	Penetration rate	9	Service channel bit rate
4	BHCA	10	Net system capability
5	Call duration	11	Alpha factor
6	Activity factor	12	Beta factor

All other quantities in the methodology are calculated values which are obtained using the equations specified in § 2 and 3 of Recommendation ITU-R M.1390 and appropriate values for the input parameters listed above. This Report should be read in conjunction with Recommendation ITU-R M.1390.

The section headings that discuss each parameter are numbered to correspond to the numbering of list of parameters above.

Service definitions for IMT-2000 are provided in Recommendation ITU-R M.816. The service definitions used in the terrestrial spectrum calculations are consistent with the Recommendation ITU-R M.816 definitions. Section 7 of Recommendation ITU-R M.816 considers IMT-2000 application services whilst Recommendation ITU-R M.1390 considers bearer services, i.e. services defined in terms of transmission bit rate, rather than the use to which such capacity is put. The analogy in landline telephone terminology would be to describe circuits as DS-1, E1, VC2, which are defined in terms of user bit rate, instead of as voice, data, or video links, since a given data stream may be used to carry a variety of information types.

The bearer services used in the spectrum calculations are categorized as follows:

a) *Speech service:* For the purposes of this Report, this service is to be considered toll quality voice service.

b) *Simple messaging:* This type of service is characterized by user bit rates of up to 14 kbit/s.

c) *Switched data:* This type of service is circuit switched and is characterized by user bit rates of up to 64 kbit/s.

d) *Asymmetrical multimedia services:* This type of service is characterized by more traffic flowing in one direction than the other. In this Report, it is assumed that the higher rate of flow is to the terminal, whilst the lower rate is from the terminal. Some examples of such services include file download, Internet browsing, full motion video, and non-interactive telemedicine. Two types of asymmetrical services are being considered in this Report:

– HMM: a user bit rate of 2 000 kbit/s in one direction and 128 kbit/s in the other;

– MMM: a user bit rate of 384 kbit/s in one direction and 64 kbit/s in the other.

For some applications, the asymmetry between the downlink and uplink traffic may be reversed.

e) *Symmetrical multimedia services:* For the purposes of this study, multimedia services are generally considered voice and/or high-speed data and/or video and/or image services. Symmetrical multimedia service is characterized by an equal amount of traffic flowing in both directions. An example of such service is high fidelity audio, videoconferencing, telemedicine and various videoconferencing applications (including but not limited to interactive services such as telemedicine) and two-way image transfer. These services are circuit switched to accommodate the real-time constraints of the applications. Two types of symmetrical multimedia services are being considered in this Report:

– a user bit rate of 128 kbit/s in each direction;

– a user bit rate of 384 kbit/s in each direction.

However, it is only necessary to consider 128/128 service as the basic symmetrical multimedia building block which will be denoted as HIMM. This is because rates such as 384/384 can be handled by appropriate multiples of the basic 128/128 building block rate. In particular 384/384 is three times the 128/128 rate.

Phase II: The current plan for IMT-2000 services is that they are to be implemented in phases. Phase I of IMT-2000 includes those services supported by user bit rates up to 2 000 kbit/s. Phase II IMT-2000 services is envisaged as augmenting Phase I new services, some of which may require higher bit rates. Phase II services could be considered as those services with user bit rates greater than 2 Mbit/s and less than 10 Mbit/s. An example of this service would be high resolution video. Since Phase II services are not yet clearly defined, and it was not expected that IMT-2000 radio interface(s) would provide them in a first stage, it was difficult to get market statistics for these services. Therefore, even for the year 2010, Phase II services have not been taken into account in this Report. Certainly, the addition of Phase II services in the time period under study would potentially increase the spectrum requirement.

Each service does not have to be available in each environment. Nevertheless, some environments are more suited to multiple services than others, and will have corresponding traffic demands. For example, compare the pedestrian environment, where the service mix is likely to include all of the services, with the vehicular environment, where there is likely to be considerably less demand for the full-motion video and high-interactivity applications provided via HMM, HIMM, and future Phase II services. Thus, a single type of service (or a few types of service) may be the dominant spectrum need driver for a given environment and geographic population density. It should be noted that the value assessed by a customer to a service or a portfolio of services may be directly related to the ubiquity of the service both geographically and by environment. In the calculation methodology, the input parameters are typically assigned subscripts «e» and «s», to enable different values to be assigned for differing environments and services (see Recommendation ITU-R M.1390).

1 Population density

Recommendation ITU-R M.1390 defines the population density as "the number of persons per unit area within the environment under consideration". This includes not only the number of inhabitants in the area, but also mainly commuters and shoppers, i.e. people who are in the environment at a given point in time for the need of their business or for their leisure.

Inside a building, a three dimensional model should be used. In selecting the number of floors that are representative, consideration must be given to management of interference levels on adjacent floors. The interference levels from uncoordinated cells above and below the floor under consideration are considered to be equivalent each to an increase by one half of the floor population density. Hence, a two-floor model has been selected for the purposes of in-building population density. Although this effect could be identified in the system capability factor, it is included in the population density in order to allow a common system capability value to be utilized across the three environments. A density of 140 000 people/km^2 corresponds therefore to 70 000 people/floor/km^2, i.e. on average one person in 14 m^2 of floor space, characteristic of an office environment.

Urban-pedestrian population densities are highly dependent on the demographic situation in the cities considered in this calculation. An investigation of this situation is difficult, as demographic data usually include only the number of inhabitants. However, information can be found in the 1999 World Almanac (based on United Nations estimates), and in the UMTS Forum Report (based on European Commission documents (see Note 1)). Most cities in Europe, Middle-East (Region 1) and Asia (Region 3) have a very high density of people in the streets as a mix of commuters together with inhabitants, in the areas where most spectrum is needed. The characteristics of urbanised areas in America (Region 2) are however different and the most dense parts of the cities are less crowded. In the urban-pedestrian environment, the density is 100 000 people/km^2 for Region 1 and Region 3. It is 75 000 people/km^2 in Region 2. This is representative of highly populated pedestrian areas (office and shopping districts).

In the urban-vehicular environment, the density is 3 000 people/km^2.

NOTE 1 – UMTS Forum Report No. 6 Spectrum For UMTS/IMT-2000, http://www.umts-forum.org CEC Deliverable R2066/SESA/GA2/DS/P/030/b1. Results of traffic modelling for UMTS. CEC Deliverable R2066/SESA/GA2/DS/P/079/b1. Traffic modelling for UMTS and evaluation studies.

2 Cell area

While the technology may provide the capability for very high cell densities, practical difficulties in finding sites and getting authorization to operate them often arise, and can control the density of cells. Hence the selection of the cell radius parameter value reflects the balance of technical, engineering and economic considerations.

2.1 High density in-building environment (Central business district (CBD)

The in-building cell is taken to have an area of 5 000 m^2. If the cell were considered as circular, then the equivalent diameter would be about 80 m. If it is considered as a square, then the size would be about 70 m × 70 m. In an office floor of 200 m × 200 m, there would be an average of 8 cells (sites) per floor.

2.2 Urban pedestrian environment

The urban pedestrian cell area is taken to have an area of 312 000 m^2. This can be considered as a square of 560 m × 560 m or a circle with a diameter of 630 m. It is considered that pedestrians would be able to move widely within this area, since it will consist of a combination of roadways, pedestrian areas, open spaces, and buildings.

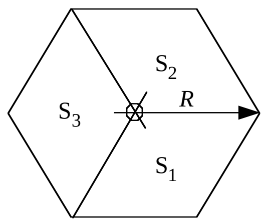
2.3 Urban vehicular environment

The urban vehicular cell size is a determining factor in the economy of deployment of the network. In certain geographic areas, operators cannot afford building small cells for the vehicular environment hence a need to deploy systems with larger cell coverage areas for a given site. It is considered that in Regions 1 and 2 an appropriate value for the urban vehicular cell area is 866 000 m^2. In Region 3, smaller cell sizes can be used, and the cell area used is 312 000 m^2.

For the purpose of illustration, the 866 000 m^2 cell can be considered to be one sector of a tri-sectored hexagon, with an average radius to vertex of about 1 000 m. This geometry is shown in Fig. 1.

FIGURE 1

Urban cell is one sector of an hexagon



S_1, S_2, S_3: Sectors
R: Radius

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Similarly, the 312 000 m^2 cell can be considered to be one sector of a tri-sectored hexagon, with an average radius to vertex of about 600 m.

Given an average radius to vertex of about 1 000 m in a hexagon cell, the closest distance between neighbouring sites is about 1 700 m centre to centre. Given an average radius to vertex of about 600 m, the closest distance between neighbouring sites is about 1 000 m centre to centre. It should be noted that whilst coverage is possible across the whole of this area, typically only a small proportion of this area will be occupied by roadways, and therefore vehicles will usually be present in only a small part of this area.

3 Penetration rate

Penetration rates are defined as the ratio of terrestrial land mobile subscribers for each service, and the total number of persons present in a representative area under consideration (e.g. a cell area of 1 km^2 or equivalent). In marketing terms, this is referred to as the demand estimate which is defined as the percentage of total population subscribing to a specific service. Individuals may have multiple subscriptions to mobile services and individuals may use more than one service.

The penetration rate is the ratio of the number of people subscribing to the service «s» over the total population, in environment «e». It should be noted that the use of each service is not exclusive. Each penetration rate refers to the penetration of that service as a proportion of the total potential user base. Since users can use more than one service it is possible for the *total* penetration in an environment (across all services) to exceed one (100%) if a high proportion of users are using more than one service.

These market figures for each of the representative service types are presented by environment and are expressed as penetration rates. Industry analyses in Regions 1, 2, and 3 that address IMT-2000 market forecasts were submitted in 1998 to ITU-R by several administrations. The analyses were developed from market research performed by several industry associations in conjunction with well-known analysis firms. After extensive discussion among the representatives from the three Regions it was possible to develop a unified global IMT-2000 forecast. This unified forecast is a reasonable amalgamation of each individual region and truly indicates the global nature of IMT-2000 while retaining closeness to the views expressing individual regional assessments of future IMT-2000 markets. The forecast is considered to be the best available information on future demand for commercial wireless services.

It should be noted that in the unified forecast developed in ITU-R, relationships were established across bearer channel rates and penetrations. For example, 128 kbit/s at 13% penetration can be expressed equivalently, for spectrum calculation purposes, as 64 kbit/s at 26% penetration. Further, similar service types can be aggregated equivalently. For example, symmetrical multimedia services have both a 128 kbit/s and a 384 kbit/s bearer channel component. For the purposes of spectrum assessment, these may be combined into a composite 128 kbit/s demand by using a factor of 3 multiplier for converting the 384 kbit/s demand to its 128 kbit/s equivalent (three 128 kbit/s channels are needed to provision a single 384 kbit/s information stream). These equating factors must be considered when comparing service types and bearer channels among forecasting organizations and entities. Such equating analyses were applied in developing the unified global IMT-2000 forecast.

In order to estimate the usage of different services in varying environments, the penetration values given in Table 9 for the services are assumed, reflecting a convergence of the results of the market survey estimates made in the three Regions of the world. It is expected that users in many cases will subscribe to multiple services and hence use more than one service in that environment.

TABLE 9

Terrestrial penetration rate for service types across the environments considered

Services	Environments		
	High density in-building (CBD)	**Urban pedestrian**	**Urban vehicular**
S: 16 kbit/s in each direction	73%	73%	73%
SM: 14 kbit/s in each direction	40%	40%	40%
SD: 64 kbit/s in each direction	13%	13%	13%
MMM: Downlink/uplink: 384/64 kbit/s	15%	15%	15%
HMM: Downlink/uplink: 2 000/128 kbit/s	15%	15%	15%
HIMM: 128 kbit/s in each direction	25%	25%	25%

It is important to note the difference between the penetration rate, which rates only the number of subscriber in a given population, and the traffic parameters, which describe the behaviour of this subscribers' base. The penetration rates may be the same in two or three of the environments, if the subscriber's terminal is the same in these environments, but the difference lies in the usage. For example, it is not expected that the usage of the HMM service in urban vehicular environment will be very high, but the value in Table 9 recognizes that subscriptions exist for people in this environment, even if they are not used, and this is reflected in the traffic parameters (BHCA, call duration, activity).

The methodology applies to all terrestrial land telecommunication systems, and the market figures given above are understood as total penetration for all IMT-2000 and pre-IMT-2000 systems, including lst and 2nd generation systems. These forecast figures do not include paging type services nor dedicated land mobile radio networks such as those traditionally deployed for example, by police, municipalities, or other dedicated business use.

4 BHCA

The BHCA parameter in Table 10 defines an important part of the traffic characteristics in the spectrum estimation model. This traffic characteristic is hard to predict, especially for the multimedia services. New services will have different temporal characteristics so that the relative spectrum balance between speech and other services varies through the day. Furthermore, differentiated tariffs during the day would influence the traffic characteristics. The estimates of multimedia traffic are based on surveys performed in 1996-1998, and on the current understanding of the evolution of the overall multimedia traffic and mobile use.

TABLE 10

BHCA

Services	Environments					
	High density in-building (CBD)		Urban pedestrian		Urban vehicular	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
S: 16 kbit/s in each direction	3	3	0.8	0.8	0.4	0.4
SM: 14 kbit/s in each direction	0.6	0.6	0.3	0.3	0.2	0.2
SD: 64 kbit/s in each direction	0.2	0.2	0.2	0.2	0.02	0.02
MMM: Downlink/uplink: 384/64 kbit/s	0.5	0.5	0.4	0.4	0.008	0.008
HMM: Downlink/uplink: 2000/128 kbit/s	0.15	0.15	0.06	0.06	0.008	0.008
HIMM: 128 kbit/s in each direction	0.14	0.14	0.070	0.070	0.011	0.011

5 Call duration

Values for the call duration parameter are provided in Table 11; these values are based on a literature research [Anderlind and Zander, 1997; Jain and Routhier, 1986; UMTS].

In the case of the multimedia services, the call duration of 3 000 s may appear at first sight to be excessive. However it should be recognized that this is to be taken in conjunction with the activity factor, which takes account of the actual occupancy of the channel for such packet switched services. Further information on this subject is given in Attachment 1 to Appendix 1.

TABLE 11

Call duration (s)

Service	Environment		
	CBD	Pedestrian	Vehicular
S: 16 kbit/s in each direction	180	120	120
SM: 14 kbit/s in each direction	3	3	3
SD: 64 kbit/s in each direction	156	156	156
MMM: Downlink/uplink: 384/64 kbit/s	3 000	3 000	3 000
HMM: Downlink/uplink: 2 000/128 kbit/s	3 000	3 000	3 000
HIMM: 128 kbit/s in each direction	120	120	120

6 Activity factor

The values given below in Table 12 for the activity factor for packet switched services are based on the model given in Attachment 1 to Appendix 1.

TABLE 12

Activity factor

Services	Environments					
	High density-in building (CBD)		Urban pedestrian		Urban vehicular	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
S: 16 kbit/s in each direction	0.5	0.5	0.5	0.5	0.5	0.5
SM: 14 kbit/s in each direction	1	1	1	1	1	1
SD: 64 kbit/s in each direction	1	1	1	1	1	1
MMM: Downlink/uplink: 384/64 kbit/s	0.00285	0.015	0.00285	0.015	0.00285	0.015
HMM: Downlink/uplink: 2 000/128 kbit/s	0.00285	0.015	0.00285	0.015	0.00285	0.015
HIMM: 128 kbit/s in each direction	1	1	1	1	1	1

Typically a circuit switched service would have an activity factor of 1, since the circuit would be used in both directions for all of the time. However, in the case of speech, a value of 0.5 has been assigned, since on average, information is being conveyed in any direction for only half of the time.

7 Quality of Service (QoS)

7.1 QoS for circuit switched Erlang B model traffic

The Erlang B formula should be used in the determination of the service channels per group for the services that require circuit switched traffic engineering having low delay with full availability trunk groups. This applies to speech, switched data, and HIMM traffic. The Erlang B formula is well established as the preferred model to be applied to traffic of this type.

It is expected that end users will expect a wireless QoS that is comparable to that of the wireline network. Therefore, a sensitivity analysis was performed of the effect of changes in the QoS parameter from 2% to 1%. When varying only this parameter, the net bandwidth requirement only changed by 1.6% when all other parameters in the example calculation of Recommendation ITU-R M.1390 are left unchanged. Current trends for wireless communication services is to improve QoS beyond that available today. Consequently, there is a significant shift to engineer systems with a QoS approaching that of the fixed wireline network. Selection of QoS to be equivalent to 1% correctly reflects this trend.

7.2 QoS for packet switched Erlang C model traffic

The Erlang C formula should be used in the determination of the service channels per group for the packet communications services that are bursty in nature and traffic can be delayed beyond expected holding times when finding busy channel conditions. This includes SM, MMM, and HMM.

The session connection requests are modelled here as calls arriving at the switch, with a length which is equal to the call duration for the service. The user is considered to get a satisfactory QoS if the effective session throughput is at least equal to 50% of the nominal bit rate. This is calculated over a period of length equal to the call duration.

Queuing theory for an $M/M/S/\infty/\infty$ gives the following probability, P, that the waiting time for an arriving call is larger than x:

$$P\{W > x\} = \mathrm{E_C}(S,A) \times \exp\left[-\mu(S - A)\, x\right]$$

where:

W:	waiting time
S:	number of channels
A:	traffic
$\mathrm{E_C}(S,A)$:	probability that an arriving call is queued (Erlang C function)
$1/\mu$:	average call duration.

To achieve the satisfied user criterion, it is necessary that the waiting time be below 50% of the call duration (i.e. all the traffic can go through in at least 50% of the length of the session). This is equivalent to saying that $\mu\, x = 0.5$.

Here again, it is expected that end users will expect a wireless QoS that is comparable to that of the wireline network. Therefore, the probability that the user is unsatisfied should be kept below 1%.

8 Number of cells per group

The number of cells per group is used to describe the number of cells considered to be grouped for the purpose of application of traffic and QoS. Seven is the chosen value for this parameter because it represents the cell in question plus the surrounding six first tier cells in a hexagonal representation of a cellular system.

9 Service channel bit rate

The service channel bit rate is the data rate of the traffic being transported, plus any necessary overhead bits (e.g. for signalling and timing). The methodology also refers to the net user bit rate, which is the data rate of the traffic alone. However, for the purposes of simplicity, and recognizing that the magnitude of the overhead is currently unknown, in this calculation the service channel bit rate has been taken to be equal to the net user bit rate.

For the purpose of the spectrum calculations, the bearer services used are considered to have the following bit rates:

TABLE 13

Bearer services

Service	User bit rate
S	16 kbit/s
SM	14 kbit/s
SD	64 kbit/s
Asymmetrical multimedia services	HMM: 2 000 kbit/s in one direction and 128 kbit/s in the other MMM: 384 kbit/s in one direction and 64 kbit/s in the other
Symmetrical multimedia services	Two types of symmetrical multimedia services are being considered in this Report: – 128 kbit/s in each direction – 384 kbit/s in each direction However, it is only necessary to consider the 128 kbit/s service as the basic symmetrical multimedia building block which will be denoted as HIMM. This is because rates such as 384 kbit/s can be handled by appropriate multiples of the basic 128 kbit/s building block rate (i.e. 384 kbit/s is three times 128 kbit/s).

10 Net system capability

Net system capability values represent average values for cells carrying mixed traffic in a loaded network during the busy hour. These values are used to estimate the total spectrum requirement for public mobile communications in the year 2010, including both 2nd and 3rd generation systems. The system capability of IMT-2000 alone can be expected to be higher.

Different values are to be applied for speech and for other services. It is foreseen that in 2010 a part of the speech traffic will still be carried by 2nd generation systems, but (for example) high bit rate data traffic will be carried by 3rd generation only.

The total terrestrial spectrum requirement is inversely proportional to the value used for the net system capability parameter, i.e. if the net system capability parameter is doubled then the total spectrum requirement is reduced by a factor of 2.

Although the net system capability is related to the spectrum efficiencies, the two quantities are not the same. The spectral efficiencies of the IMT-2000 radio interface(s) are theoretical estimates. The evaluation of capacity figures is a very complex task, and the results depend a lot on scenarios and assumptions used, as well as the modelling assumptions of a radio access system.

The system capabilities are traditionally developed by means of simulations and validated in deployed systems. The system capability for speech for a mixture of 2nd and 3rd generation systems will likely vary from 40 kbit/s/MHz/cell to 100 kbit/s/MHz/cell, while that for other services will likely vary from 50 kbit/s/MHz/cell to 200 kbit/s/MHz/cell, depending largely on the scenarios and assumptions used. The net system capability must reflect real-world issues resulting from the actual implementation and fielding of wireless systems. Therefore the spectral efficiencies in the IMT-2000 radio interface(s) proposals/evaluations cannot be used directly as a parametric value for net system capability.

A review of the radio interface(s) that are being considered for IMT-2000 standardization indicates that these technologies will rely on a number of capacity-enhancing techniques as part of the basic system design and deployment. Hence, it is unlikely that additional techniques and technologies would be forthcoming in a sufficient time-frame to allow the effective net system capability to be significantly increased over that proposed.

There will be a mix of existing 2nd generation technologies and 3rd generation technologies deployed in the year 2010 so that the system capability factor would be a blended value for each IMT-2000 service type. For example, almost all data and certainly the wideband data in 2010 can be expected to be carried over 3rd generation technology while voice and some amount of lower speed data will still be accommodated by existing technologies. It is also expected that any new spectrum made available for IMT-2000 (i.e. spectrum beyond that already allocated for 1st and 2nd generation systems) will utilize 3rd generation technologies.

The percentage of 2nd and 3rd generation systems deployed by 2010 is expected to vary somewhat between Regions. This is because of the relative amount of spectrum available today deployed with 2nd generations systems versus the amount of new spectrum anticipated for 3rd generation systems varies. This can be observed by examining Table 14.

TABLE 14

Global mobile terrestrial spectrum requirements by service classes

	1G and 2G services (S, SM, SD) (MHz)	3G new services (MMM, HMM, and HIMM) (MHz)	Ratio of new 3G services to 1G and 2G services
Region 1	269	286	1.06
Region 2	174	216	1.24
Region 3	232	248	1.07

NOTE 1 – It is recognized that 3G services include the 1G and 2G services, but Table 14 is constructed to delineate the higher data rate 3G services spectrum requirement from the speech and lower data rate services spectrum requirement.

Consequently, it has been concluded that a net system capability of 150 kbit/s/MHz/cell for data communications services and 100 kbit/s/MHz/cell for speech services are used in the calculations for Region 2, while for Regions 1 and 3 values of 125 kbit/s/MHz/cell for data and 70 kbit/s/MHz/cell for speech services are used in the calculations. However, it should be noted that this does not imply that there is any difference in spectral efficiency of similar IMT-2000 deployments in the three Regions.

11 Alpha factor

The weighting factor, α, provides appropriate weighting in the spectrum requirements calculations to take account of factors which may be specific to a particular environment or service, and includes the following:

– weighting to adjust for geographical offsets in overlapping environments;

– weighting to correct for non-simultaneous busy hour traffic requirements.

The weighting factor, α, has a default value of unity, as stated in Recommendation ITU-R M.1390. Consideration of the traffic forecasts, geographical environments and other parameter values used in these calculations for non-simultaneous busy hour and geographic offset impacts indicates that the value of unity is the most applicable choice.

12 Beta factor

The Beta factor, which is independent of any particular environment or service, provides for impacts such as:

– guardbands;

– multiple networks and operators:

  – reduced trunking efficiency,

  – modularity of spectrum.

Specifically, the Beta factor accounts for the fact that additional spectrum will be needed if administrations decide to license multiple operators.

12.1 Guardbands

Guardbands have to be accommodated between two operators, or equivalently the impact of capacity reduction due to adjacent bands effects, should be taken into account. Guardbands have to be accommodated also at the boundaries between mobile and other services, and this effect is all the more increased as spectrum is more fragmented and the number of boundaries is increased. An average value of the guardband component of Beta to compensate for this loss of spectrum is estimated to be 1.04.

12.2 Impact of multiple networks/operators

Analysis across Regions indicates that there is a wide range in the number of networks/operators. With regard to selection of appropriate values for the number of networks/operators, it is recognized that any decisions on the number of networks/operators will be subject to national/regional policies. These policies could have an impact on the specific amount of spectrum required within a country or Region.

There are two components of Beta that are dependent on the number of networks/operators (trunking efficiency and modularity). For the purpose of developing the future requirements for terrestrial spectrum for IMT-2000 the following values shown in Tables 15 and 16 were considered to be representative of the Regions. The definition and specific examples of the trunking efficiency and modularity components are given in § 12.2.1 and 12.2.2.

TABLE 15

Impacts on trunking efficiency

Region	Trunking efficiency component
1	1.19
2	1.38
3	1.07

TABLE 16

Impacts of modularity of spectrum

Region	Modularity component
1	1.042
2	1.019
3	1.017

The values in Tables 15 and 16 could be considered to correspond to three networks/operators for Region 1, six networks/operators for Region 2, and two networks/operators for Region 3.

12.2.1 Trunking efficiency component of the Beta factor

Each individual network in a multiple operator and network environment will not carry as much traffic because of a smaller number of subscribers as compared to a single operator environment. This leads to decreased trunking efficiency and therefore increases the spectrum requirements as a function of the number of operators.

Multiple operator and network situations require that the Beta factor take account of trunking inefficiencies. For example where there are three networks, a Beta factor of 1.19 is appropriate. Where there are six networks, a Beta factor of 1.38 is appropriate. The following example is provided to assist in understanding the trunking efficiency component Beta factor.

The factor derived for trunking inefficiency as spectrum is divided into smaller and smaller segments across operators or across air interface types is well defined, based on the Erlang B formula. For example, if a total traffic demand of 80 E is to be served with a 1% blocking probability, it would require that 96 trunks (i.e. bearer channels) be provided in a single trunk group (i.e. contiguous allocation). However, if the same 80 E of traffic were divided equally among six different trunk groups (corresponding to six wireless networks with equal market share, providing equivalent service), each network's group of channels would be required to carry 80/6 or 13.33 E. The Erlang B formula for 13.33 E predicts that 22 trunks would be required to be provided by each network, or a total of 132 trunks among all networks. This is an increase of 38% over the number of trunks needed by a single network to carry the equivalent traffic. Thus, a Beta factor of 1.38 should be used if one assumes that there will be six networks each having an equal market share.

12.2.2 Modularity component of the Beta factor

12.2.2.1 5 MHz modularity

The modularity component factor has been developed to accommodate the proposed channel increments of the IMT-2000 radio interface(s) submissions considering the case of fully utilized spectrum. For example, it is appropriate to modularize the spectrum into units of spectrum having an uplink and downlink component to accommodate frequency division duplex technologies. Further, when considering the radio interface(s), a modularity that produces spectrum units that are multiples of 5 MHz as a function of the chosen number of networks is appropriate. This upward rounding to 5 MHz promotes most efficient allocation of spectrum as a technology needing a minimum of 5 MHz for a channel cannot be deployed in a spectrum unit that is not a multiple of 5 MHz. The analysis is also valid for radio interface(s) using a channelization increment narrower that 5 MHz as the assessment of spectrum need presumes that the spectrum will be fully utilized. It can also be applied to current 2nd generation technologies. In approximate terms, a technology using a single 5 MHz channel fully loaded to maximum capacity is equivalent to a technology using the same 5 MHz but deploying on many narrower channels each fully loaded.

Hence, it is most appropriate that the common denominator to ensure technology neutrality in the assessment of spectrum should be a modularity that provides for upward rounding to the nearest 5 MHz for both uplink and downlink as a function of the number of networks. This 5 MHz modularity can be expressed as a percentage of the value of spectrum calculated in the methodology prior to applying Beta and can be recursively developed to correctly reflect the 5 MHz requirement in both uplink and downlink.

12.2.2.2 Determination of modularity impact

In understanding the application and development of the impact of modularity on the spectrum requirement a detailed example provides guidance.

For example in considering six networks, there are twelve units of spectrum, six uplink and six downlink that must be considered. If the total uplink spectrum was divided by six and the downlink as well and a 5 MHz upward rounding modularity applied, this would give the absolute amount of extra spectrum required for modularity which could be expressed as a percentage of the spectrum required.

Continuing the example, if the downlink calculation prior to the modularity component of Beta was 269.0 MHz, for six networks we would divide 269.0 by 6 which is 44.83 and upward round to the nearest 5 MHz, to get **45**. The total difference is 6 times (45 – 44.83) or 1.0 MHz.

Similarly for the uplink, if the calculation prior to Beta was 113.6 MHz, for six networks we would divide 113.6 by 6 which is 18.93 and then upward round to the nearest 5 MHz, to get **20**. The total difference is 6 times (20 – 18.93) or 6.4 MHz.

Thus the total spectrum needed for modularity in this example would be 1.0 plus 6.4 or **7.4** MHz. The total spectrum (downlink plus uplink) before the modularity component of Beta is 269.0 + 113.6 or **382.6** MHz.

The modularity component of Beta is determined and applied after the other components of Beta factor so as to arrive at final total of spectrum that is expressed as a multiple of 5 MHz. In this example, the total is thus 382.6 + 7.4 or **390** MHz.

To determine the percentage that this component represents as a factor within Beta, it is necessary to divided the final modularized value (390 MHz) by the value prior to modularization (382.6 MHz) to arrive at a modularity component of Beta of 1.0194 which when incorporated as a factor within Beta is correctly expressed as (1.0194 – 1.0) or 0.0194 (1.94%) for modularity component of Beta.

For the 6 network/operator case, the downlink modularity per network/operator is 45 MHz and the uplink modularity per network/operator is 20 MHz as previously determined to give an allocation that is a multiple of 5 MHz. We thus see that for 6 networks/operators that 270 MHz is required for downlink (6 times 45 MHz) and 120 MHz (6 times 20 MHz) for uplink. *This results in a total requirement of uplink plus downlink, when considering modularity, of 390 MHz, for this example*.

This development of modularity results in the expression of the spectrum requirement for IMT-2000 that matches with channelization requirements of the IMT-2000 radio interface(s) and existing 2G technologies, adheres to the prevailing philosophy of allocating spectrum assignment in multiples of 5 MHz, provides information relative to allocation per network/operator, and further reinforces the rather unique aspect of IMT-2000 in the future for asymmetrical allocations of spectrum.

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ATTACHMENT 1

TO APPENDIX 1

Packet communications model and packet communications values

Figure 2 provides a pictorial illustration of the packet communications model that is well documented in the literature (see list of references in Appendix 2 to Annex 1). This model is based on empirical information that has been obtained from numerous packet communications traffic measurement programs. Numerous researchers have found that Poisson arrival models are not appropriate for modelling packet communication traffic. Rather, the traffic arrives in bursts or trains of data as illustrated in Fig. 2. The parameters associated with this bursty traffic are contained in Fig. 2.

This traffic model can be used to determine the activity factor for the packet communication services defined in this Report. This is illustrated in Table 17. The parameters for the model were obtained from several consistent sources listed in Table 17. The parameters are:

– number of packet-calls per session (NPCPS)
– number of packets per packet-call (NPPPC)
– number of bytes per packet (NBPP)
– packet-call inter-arrival time (PCIT) (s)
– packet inter-arrival time (PIT) (s)
– transmission rate (kbit/s).

The packet transmission time is calculated by:

$$\text{Transmission time (s)} = NPCPS \times NPPPC \times NBPP \times \text{(8 bits/byte)/1 024 bits/kB/transmission rate}$$

The total session time is calculated by:

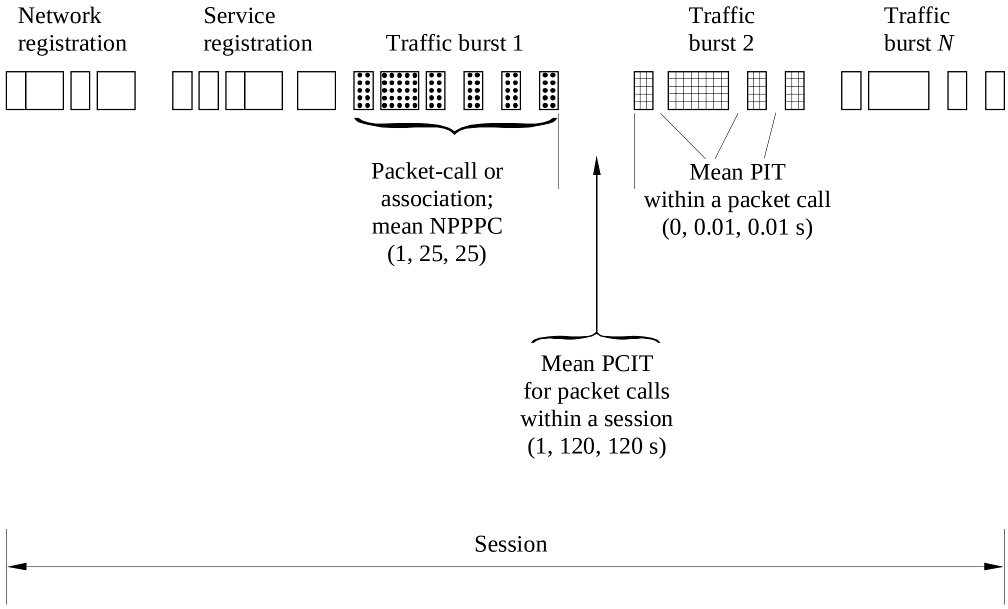
$$\text{Total session time (s)} = \text{packet transmission time} + \{[PCIT \times (NPCPS - 1)] + [PIT \times (NPPPC - 1)]\}$$

The activity factor is calculated by:

$$\text{Activity factor} = \text{(packet transmission time)/(total session time)}$$

FIGURE 2

Packet communications model



Note 1 - Mean NPCPS: 114, 5, 5 and mean NBPP: 90, 480, 90.

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TABLE 17

	Downlink HMM et MMM	Uplink HMM et MMM
NPCPS	5	5
NPPPC	25	25
NBPP	480	90
PCIT (s)	120.00	120.00
PIT (s)	0.01	0.01
Transmission rate (kbit/s)	64	64
Packet transmission time (s)	7.32	1.37
Total session time (s)	4.88×10^2	4.82×10^2
Activity factor	1.50×10^{-2}	2.85×10^{-3}

NOTE 1 – Packet-calls are often called associations in the literature.

NOTE 2 – Quantities in bold are calculated using the input parameters (not in bold) using the packet-train communications model provided in Fig. 2.

NOTE 3 – Input parameters are cdma2000 ITU-R candidate submission of 2 June 1998; the same traffic model and parameters (except for PCIT) are in the European Telecommunications Standards Institute (ETSI), TR 101 112, UMTS Selection Procedures for the Choice of Radio Transmission Technologies of the UMTS.

APPENDIX 2

TO ANNEX 1

Detailed terrestrial component spectrum calculations

This Appendix provides the output from a spreadsheet that implements the methodology defined in Recommendation ITU-R M.1390. The services and environments in Table 18 are also those defined in Recommendation ITU-R M.1390. The values used for the environment and services and market penetration parameters are proved in § 2.2 of this Report. The values used for the technical parameters are those provided in § 2.3 of this Report.

In the spreadsheets provided as Tables 18, 19 and 20, the spectrum calculation uses equation (1), from Recommendation ITU-R M.1390.

The spectrum required, $F_{Terrestrial}$ (MHz) is:

$$F_{Terrestrial} = \beta \, \Sigma \, \alpha_{es} \, F_{es} = \beta \, \Sigma \, \alpha_{es} \, T_{es}/S_{es} \tag{1}$$

where e and s are subscripts denoting dependency on environments and services respectively.

Therefore, $F_{Terrestrial}$ is the total required spectrum as a weighted summation of co-existing individual F_{es} in the same geographical area for all environments e and services s considered relevant, adjusted for influences such as spectrum sharing, multiple operators,

where:

$F_{Terrestrial}$:	terrestrial component spectrum requirement	Units: MHz
T_{es} :	trafic/cell$_{es}$	Units: Mbit/s/cell
S_{es} :	system capability	Units: Mbit/s/MHz/cell
α_{es} :	weighting factor	Units: dimensionless
β :	adjustment factor	Units: dimensionless

Equation (1) addresses both circuit and packet switched services and includes consideration for traffic asymmetry in the uplink and downlin k directions.

The parameters in Table 18 are:

– density of users
– equivalent cell diameter
– number of sectors per cell
– penetration
– BHCA
– call duration
– activity factor
– grade or QoS
– number of cells per group
– net channel bit rate
– net system capability
– Beta which provides for impacts such as multiple operators (reduced trunking/spectral efficiency and modularity); sharing with other IMT-2000 services/systems; sharing with non- IMT-2000 services/systems; guardbands.

All other quantities in Tables 18, 19 and 20 are calculated values, which are obtained using the equations of Recommendation ITU-R M.1390.

Spreadsheets are provided for calculation performed for each Region. Table 18 provides information on Region 1. Table 19 provides information on Region 2. Table 20 provides information on Region 3.

TABLE 18

Spreadsheet calculations for terrestrial component of IMT-2000 for Region 1

Spreadsheet For Calculating IMT-2000 Terrestrial Component Spectrum Requirement

	CBD	**Pedestrian**	**Vehicular**
Type	**pico**	**micro**	**macro**
Density of users	140000	100000	3000
Equivalent cell diameter	0.08	0.60	1.00
Number of sectors	1	3	3
Cell Area	5.03E-03	3.12E-01	8.66E-01
Penetration 2010	**CBD**	**Pedestrian**	**Vehicular**
HIMM	25%	25%	25%
HMM	15%	15%	15%
MMM	15%	15%	15%
SD	13%	13%	13%
SM	40%	40%	40%
S	73%	73%	73%
Users/Cell	**CBD**	**Pedestrian**	**Vehicular**
HIMM	176	7794	650
HMM	106	4677	390
MMM	106	4677	390
SD	91	4053	338
SM	281	12471	1039
S	514	22759	1897
BHCA	**CBD**	**Pedestrian**	**Vehicular**
HIMM	0.14	0.07	0.011
HMM	0.15	0.06	0.008
MMM	0.5	0.4	0.008
SD	0.2	0.2	0.02
SM	0.6	0.3	0.2
S	3	0.8	0.4
Call duration	**CBD**	**Pedestrian**	**Vehicular**
HIMM	120	120	120
HMM	3000	3000	3000
MMM	3000	3000	3000
SD	156	156	156
SM	3	3	3
S	180	120	120
Activity factor UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.00285	0.00285	0.00285
MMM	0.00285	0.00285	0.00285
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5
Activity factor DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.015	0.015	0.015
MMM	0.015	0.015	0.015
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5

	Net BR UL	Net BR DL	Ch BR UL	Ch BR DL	Capability UL	Capability DL
HIMM	128	128	128	128	125	125
HMM	128	2000	128	2000	125	125
MMM	64	384	64	384	125	125
SD	64	64	64	64	125	125
SM	14	14	14	14	125	125
S	16	16	16	16	70	70

Traffic/User UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	16.80	8.40	1.32
HMM	1.28	0.51	0.07
MMM	4.28	3.42	0.07
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Traffic/User DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	16.80	8.40	1.32
HMM	6.75	2.70	0.36
MMM	22.50	18.00	0.36
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Off_Traffic/Cell UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	2.96E+03	6.55E+04	8.57E+02
HMM	1.35E+02	2.40E+03	2.67E+01
MMM	4.51E+02	1.60E+04	2.67E+01
SD	2.85E+03	1.26E+05	1.05E+03
SM	5.07E+02	1.12E+04	6.24E+02
S	1.39E+05	1.09E+06	4.55E+04

Off_Traffic/Cell DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	2.96E+03	6.55E+04	8.57E+02
HMM	7.13E+02	1.26E+04	1.40E+02
MMM	2.38E+03	8.42E+04	1.40E+02
SD	2.85E+03	1.26E+05	1.05E+03
SM	5.07E+02	1.12E+04	6.24E+02
S	1.39E+05	1.09E+06	4.55E+04

Traffic/Group UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	5.75	127.31	1.67
HMM	0.26	4.66	0.05
MMM	0.88	31.10	0.05
SD	5.55	245.88	2.05
SM	0.99	21.82	1.21
S	269.70	2124.19	88.51

Traffic/Group DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	5.75	127.31	1.67
HMM	1.39	24.55	0.27
MMM	4.62	163.68	0.27
SD	5.55	245.88	2.05
SM	0.99	21.82	1.21
S	269.70	2124.19	88.51

Servi_Ch/Group UL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	146	6	B	0.01	
HMM	3	9	2	C	0.01	0.5
MMM	4	38	2	C	0.01	0.5
SD	12	269	7	B	0.01	
SM	4	28	4	C	0.01	0.5
S	293	2152	105	B	0.01	

Servi_Chl/Group DL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	146	6	B	0.01	
HMM	5	31	3	C	0.01	0.5
MMM	9	172	3	C	0.01	0.5
SD	12	269	7	B	0.01	
SM	4	28	4	C	0.01	0.5
S	293	2152	105	B	0.01	

Servi_Ch/Cell UL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.71	20.86	0.86	7
HMM	0.43	1.29	0.29	
MMM	0.57	5.43	0.29	
SD	1.71	38.43	1.00	
SM	0.57	4.00	0.57	
S	41.86	307.43	15.00	

Servi_Chl/Cell DL	CBD	Pedestrian	Vehicular
HIMM	1.71	20.86	0.86
HMM	0.71	4.43	0.43
MMM	1.29	24.57	0.43
SD	1.71	38.43	1.00
SM	0.57	4.00	0.57
S	41.86	307.43	15.00

Traffic UL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.67	0.11
HMM	0.05	0.16	0.04
MMM	0.04	0.35	0.02
SD	0.11	2.46	0.06
SM	0.01	0.06	0.00800
S	0.67	4.92	0.24

Traffic DL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.67	0.11
HMM	1.43	8.86	0.86
MMM	0.49	9.44	0.16
SD	0.11	2.46	0.06
SM	0.01	0.06	0.00800
S	0.67	4.92	0.24

Req Band UL	CBD	Pedestrian	Vehicular	
HIMM	1.76	21.36	0.88	23.99
HMM	0.44	1.32	0.29	2.05
MMM	0.29	2.78	0.15	3.22
SD	0.88	19.68	0.51	21.07
SM	0.06	0.45	0.06	0.58
S	9.57	70.27	3.43	83.27
Sum	13.00	115.85	5.32	**134.16**

Req Band DL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.76	21.36	0.88	23.99
HMM	11.43	70.86	6.86	89.14
MMM	3.95	75.48	1.32	80.75
SD	0.88	19.68	0.51	21.07
SM	0.06	0.45	0.06	0.58
S	9.57	70.27	3.43	83.27
Sum	27.64	258.09	13.06	**298.79**

UL+DL	CBD	Pedestrian	Vehicular	Total
HIMM	3.51	42.72	1.76	47.98
HMM	11.87	72.17	7.15	91.19
MMM	4.24	78.26	1.46	83.97
SD	1.76	39.35	1.02	42.13
SM	0.13	0.90	0.13	1.15
S	19.13	140.54	6.86	166.53
Sum	40.64	373.94	18.38	**432.95**

Calculation of Beta Factor for Guardbands, Spectrum Modularity, and Spectrum Inefficiencies of Multiple Networks

Number of Networks/Operators Considered	3
Trunking Factor of Multiple Networks	19.00%
Guardbands	4.00%
Beta factor before modularity	1.230

Applying the Guardband and Multiple Network component of Beta:

UPLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	165
DOWNLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	368
Total Spectrum (Uplink +Downlink) before modularity	**533**

Applying the Modularity component of Beta for a 5 MHz minimum spectrum subdivision to give a multiple of 5 MHz boundaries for the division of spectrum across the separate networks/operators:

Number of Networks Considered =	3		
		diff uplink MHz=	15.0
Beta Modularity Component (applied to total spectrum)	4.22%	diff downlink MHz=	7.5
		diff total MHz=	22.5
TOTAL SPECTRUM REQUIREMENT (Uplink + Downlink)	**555**		

Breakdown by direction of transmission and modularity per network:

Uplink spectrum requirement after 5 MHz subdivision modularity	180	mod per network =	60.00 MHz
Downlink spectrum requirement after 5 MHz subdivision modularity	375	mod per network =	125.00 MHz

Note**:** This breakdown of the total requirement shows the asymmetry of required spectrum due to asymmetrical multimedia traffic flows in IMT-2000.

The modularity per network value gives the required spectrum for the selected number of networks on a per network basis for uplink and downlink.

TABLE 19

Spreadsheet calculations for terrestrial component of IMT-2000 for Region 2

Spreadsheet For Calculating IMT-2000 Terrestrial Component Spectrum Requirement

Type	**CBD pico**	**Pedestrian micro**	**Vehicular macro**
Density of users	140000	75000	3000
Equivalent cell diameter	0.08	0.60	1.00
Number of sectors	1	3	3
Cell Area	5.03E-03	3.12E-01	8.66E-01

Penetration 2010	**CBD**	**Pedestrian**	**Vehicular**
HIMM	25%	25%	25%
HMM	15%	15%	15%
MMM	15%	15%	15%
SD	13%	13%	13%
SM	40%	40%	40%
S	73%	73%	73%

Users/Cell	**CBD**	**Pedestrian**	**Vehicular**
HIMM	176	5846	650
HMM	106	3507	390
MMM	106	3507	390
SD	91	3040	338
SM	281	9353	1039
S	514	17069	1897

BHCA	**CBD**	**Pedestrian**	**Vehicular**
HIMM	0.14	0.07	0.011
HMM	0.15	0.06	0.008
MMM	0.5	0.4	0.008
SD	0.2	0.2	0.02
SM	0.6	0.3	0.2
S	3	0.8	0.4

Call duration	**CBD**	**Pedestrian**	**Vehicular**
HIMM	120	120	120
HMM	3000	3000	3000
MMM	3000	3000	3000
SD	156	156	156
SM	3	3	3
S	180	120	120

Activity factor UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.00285	0.00285	0.00285
MMM	0.00285	0.00285	0.00285
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5

Activity factor DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.015	0.015	0.015
MMM	0.015	0.015	0.015
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5

	Net BR UL	Net BR DL	Ch BR UL	Ch BR DL	Capability UL	Capability DL
HIMM	128	128	128	128	150	150
HMM	128	2000	128	2000	150	150
MMM	64	384	64	384	150	150
SD	64	64	64	64	150	150
SM	14	14	14	14	150	150
S	16	16	16	16	100	100

Traffic/User UL	CBD	Pedestrian	Vehicular
HIMM	16.80	8.40	1.32
HMM	1.28	0.51	0.07
MMM	4.28	3.42	0.07
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Traffic/User DL	CBD	Pedestrian	Vehicular
HIMM	16.80	8.40	1.32
HMM	6.75	2.70	0.36
MMM	22.50	18.00	0.36
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Off_Traffic/Cell UL	CBD	Pedestrian	Vehicular
HIMM	2.96E+03	4.91E+04	8.57E+02
HMM	1.35E+02	1.80E+03	2.67E+01
MMM	4.51E+02	1.20E+04	2.67E+01
SD	2.85E+03	9.48E+04	1.05E+03
SM	5.07E+02	8.42E+03	6.24E+02
S	1.39E+05	8.19E+05	4.55E+04

Off_Traffic/Cell DL	CBD	Pedestrian	Vehicular
HIMM	2.96E+03	4.91E+04	8.57E+02
HMM	7.13E+02	9.47E+03	1.40E+02
MMM	2.38E+03	6.31E+04	1.40E+02
SD	2.85E+03	9.48E+04	1.05E+03
SM	5.07E+02	8.42E+03	6.24E+02
S	1.39E+05	8.19E+05	4.55E+04

Traffic/Group UL	CBD	Pedestrian	Vehicular
HIMM	5.75	95.48	1.67
HMM	0.26	3.50	0.05
MMM	0.88	23.32	0.05
SD	5.55	184.41	2.05
SM	0.99	16.37	1.21
S	269.70	1593.14	88.51

Traffic/Group DL	CBD	Pedestrian	Vehicular
HIMM	5.75	95.48	1.67
HMM	1.39	18.41	0.27
MMM	4.62	122.76	0.27
SD	5.55	184.41	2.05
SM	0.99	16.37	1.21
S	269.70	1593.14	88.51

Servi_Ch/Group UL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	113	6	B	0.01	
HMM	3	8	2	C	0.01	0.5
MMM	4	30	2	C	0.01	0.5
SD	12	205	7	B	0.01	
SM	4	22	4	C	0.01	0.5
S	293	1622	105	B	0.01	

Servi_Chl/Group DL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	113	6	B	0.01	
HMM	5	24	3	C	0.01	0.5
MMM	9	131	3	C	0.01	0.5
SD	12	205	7	B	0.01	
SM	4	22	4	C	0.01	0.5
S	293	1622	105	B	0.01	

Servi_Ch/Cell UL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.71	16.14	0.86	7
HMM	0.43	1.14	0.29	
MMM	0.57	4.29	0.29	
SD	1.71	29.29	1.00	
SM	0.57	3.14	0.57	
S	41.86	231.71	15.00	

Servi_Chl/Cell DL	CBD	Pedestrian	Vehicular
HIMM	1.71	16.14	0.86
HMM	0.71	3.43	0.43
MMM	1.29	18.71	0.43
SD	1.71	29.29	1.00
SM	0.57	3.14	0.57
S	41.86	231.71	15.00

Traffic UL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.07	0.11
HMM	0.05	0.15	0.04
MMM	0.04	0.27	0.02
SD	0.11	1.87	0.06
SM	0.01	0.04	0.00800
S	0.67	3.71	0.24

Traffic DL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.07	0.11
HMM	1.43	6.86	0.86
MMM	0.49	7.19	0.16
SD	0.11	1.87	0.06
SM	0.01	0.04	0.00800
S	0.67	3.71	0.24

Req Band UL	CBD	Pedestrian	Vehicular	
HIMM	1.46	13.78	0.73	15.97
HMM	0.37	0.98	0.24	1.58
MMM	0.24	1.83	0.12	2.19
SD	0.73	12.50	0.43	13.65
SM	0.05	0.29	0.05	0.40
S	6.70	37.07	2.40	46.17
Sum	9.55	66.44	3.98	**79.97**

Req Band DL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.46	13.78	0.73	15.97
HMM	9.52	45.71	5.71	60.95
MMM	3.29	47.91	1.10	52.30
SD	0.73	12.50	0.43	13.65
SM	0.05	0.29	0.05	0.40
S	6.70	37.07	2.40	46.17
Sum	21.76	157.26	10.42	**189.44**

UL+DL	CBD	Pedestrian	Vehicular	Total
HIMM	2.93	27.55	1.46	31.94
HMM	9.89	46.69	5.96	62.54
MMM	3.54	49.74	1.22	54.49
SD	1.46	24.99	0.85	27.31
SM	0.11	0.59	0.11	0.80
S	13.39	74.15	4.80	92.34
Sum	31.31	223.70	14.40	**269.42**

Calculation of Beta Factor for Guardbands, Spectrum Modularity, and Spectrum Inefficiencies of Multiple Networks

Number of Networks/Operators Considered	6
Trunking Factor of Multiple Networks	38.00%
Guardbands	4.00%
Beta factor before modularity	1.420

Applying the Guardband and Multiple Network component of Beta:

UPLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	114
DOWNLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	269
Total Spectrum (Uplink +Downlink) before modularity	**383**

Applying the Modularity component of Beta for a 5 MHz minimum spectrum subdivision to give a multiple of 5 MHz boundaries for the division of spectrum across the separate networks/operators:

Number of Networks Considered =	6		
		diff uplink MHz=	6.4
Beta Modularity Component (applied to total spectrum)	1.94%	diff downlink MHz=	1.0
		diff total MHz=	7.4
TOTAL SPECTRUM REQUIREMENT (Uplink + Downlink)	**390**		

Breakdown by direction of transmission and modularity per network:

Uplink spectrum requirement after 5 MHz subdivision modularity	120	mod per network =	20.00 MHz
Downlink spectrum requirement after 5 MHz subdivision modularity	270	mod per network =	45.00 MHz

Note: This breakdown of the total requirement shows the asymmetry of required spectrum due to asymmetrical multimedia traffic flows in IMT-2000.

The modularity per network value gives the required spectrum for the selected number of networks on a per network basis for uplink and downlink.

TABLE 20

Spreadsheet calculations for terrestrial component of IMT-2000 for Region 3

Spreadsheet For Calculating IMT-2000 Terrestrial Component Spectrum Requirement

	CBD	**Pedestrian**	**Vehicular**
Type	**pico**	**micro**	**macro**
Density of users	140000	100000	3000
Equivalent cell diameter	0.08	0.60	0.60
Number of sectors	1	3	3
Cell Area	5.03E-03	3.12E-01	3.12E-01

Penetration 2010	**CBD**	**Pedestrian**	**Vehicular**
HIMM	25%	25%	25%
HMM	15%	15%	15%
MMM	15%	15%	15%
SD	13%	13%	13%
SM	40%	40%	40%
S	73%	73%	73%

Users/Cell	**CBD**	**Pedestrian**	**Vehicular**
HIMM	176	7794	234
HMM	106	4677	140
MMM	106	4677	140
SD	91	4053	122
SM	281	12471	374
S	514	22759	683

BHCA	**CBD**	**Pedestrian**	**Vehicular**
HIMM	0.14	0.07	0.011
HMM	0.15	0.06	0.008
MMM	0.5	0.4	0.008
SD	0.2	0.2	0.02
SM	0.6	0.3	0.2
S	3	0.8	0.4

Call duration	**CBD**	**Pedestrian**	**Vehicular**
HIMM	120	120	120
HMM	3000	3000	3000
MMM	3000	3000	3000
SD	156	156	156
SM	3	3	3
S	180	120	120

Activity factor UL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.00285	0.00285	0.00285
MMM	0.00285	0.00285	0.00285
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5

Activity factor DL	**CBD**	**Pedestrian**	**Vehicular**
HIMM	1	1	1
HMM	0.015	0.015	0.015
MMM	0.015	0.015	0.015
SD	1	1	1
SM	1	1	1
S	0.5	0.5	0.5

	Net BR UL	Net BR DL	Ch BR UL	Ch BR DL	Capability UL	Capability DL
HIMM	128	128	128	128	125	125
HMM	128	2000	128	2000	125	125
MMM	64	384	64	384	125	125
SD	64	64	64	64	125	125
SM	14	14	14	14	125	125
S	16	16	16	16	70	70

Traffic/User UL	CBD	Pedestrian	Vehicular
HIMM	16.80	8.40	1.32
HMM	1.28	0.51	0.07
MMM	4.28	3.42	0.07
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Traffic/User DL	CBD	Pedestrian	Vehicular
HIMM	16.80	8.40	1.32
HMM	6.75	2.70	0.36
MMM	22.50	18.00	0.36
SD	31.20	31.20	3.12
SM	1.80	0.90	0.60
S	270.00	48.00	24.00

Off_Traffic/Cell UL	CBD	Pedestrian	Vehicular
HIMM	2.96E+03	6.55E+04	3.09E+02
HMM	1.35E+02	2.40E+03	9.60E+00
MMM	4.51E+02	1.60E+04	9.60E+00
SD	2.85E+03	1.26E+05	3.79E+02
SM	5.07E+02	1.12E+04	2.24E+02
S	1.39E+05	1.09E+06	1.64E+04

Off_Traffic/Cell DL	CBD	Pedestrian	Vehicular
HIMM	2.96E+03	6.55E+04	3.09E+02
HMM	7.13E+02	1.26E+04	5.05E+01
MMM	2.38E+03	8.42E+04	5.05E+01
SD	2.85E+03	1.26E+05	3.79E+02
SM	5.07E+02	1.12E+04	2.24E+02
S	1.39E+05	1.09E+06	1.64E+04

Traffic/Group UL	CBD	Pedestrian	Vehicular
HIMM	5.75	127.31	0.60
HMM	0.26	4.66	0.02
MMM	0.88	31.10	0.02
SD	5.55	245.88	0.74
SM	0.99	21.82	0.44
S	269.70	2124.19	31.86

Traffic/Group DL	CBD	Pedestrian	Vehicular
HIMM	5.75	127.31	0.60
HMM	1.39	24.55	0.10
MMM	4.62	163.68	0.10
SD	5.55	245.88	0.74
SM	0.99	21.82	0.44
S	269.70	2124.19	31.86

Servi_Ch/Group UL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	146	4	B	0.01	
HMM	3	9	2	C	0.01	0.5
MMM	4	38	2	C	0.01	0.5
SD	12	269	4	B	0.01	
SM	4	28	3	C	0.01	0.5
S	293	2152	44	B	0.01	

Servi_Chl/Group DL	CBD	Pedestrian	Vehicular	Block Formula	Blocking	Hold Activity
HIMM	12	146	4	B	0.01	
HMM	5	31	2	C	0.01	0.5
MMM	9	172	2	C	0.01	0.5
SD	12	269	4	B	0.01	
SM	4	28	3	C	0.01	0.5
S	293	2152	44	B	0.01	

Servi_Ch/Cell UL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.71	20.86	0.57	7
HMM	0.43	1.29	0.29	
MMM	0.57	5.43	0.29	
SD	1.71	38.43	0.57	
SM	0.57	4.00	0.43	
S	41.86	307.43	6.29	

Servi_Chl/Cell DL	CBD	Pedestrian	Vehicular
HIMM	1.71	20.86	0.57
HMM	0.71	4.43	0.29
MMM	1.29	24.57	0.29
SD	1.71	38.43	0.57
SM	0.57	4.00	0.43
S	41.86	307.43	6.29

Traffic UL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.67	0.07
HMM	0.05	0.16	0.04
MMM	0.04	0.35	0.02
SD	0.11	2.46	0.04
SM	0.01	0.06	0.00600
S	0.67	4.92	0.10

Traffic DL	CBD	Pedestrian	Vehicular
HIMM	0.22	2.67	0.07
HMM	1.43	8.86	0.57
MMM	0.49	9.44	0.11
SD	0.11	2.46	0.04
SM	0.01	0.06	0.00600
S	0.67	4.92	0.10

Req Band UL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.76	21.36	0.59	23.70
HMM	0.44	1.32	0.29	2.05
MMM	0.29	2.78	0.15	3.22
SD	0.88	19.68	0.29	20.85
SM	0.06	0.45	0.05	0.56
S	9.57	70.27	1.44	81.27
Sum	13.00	115.85	2.80	**131.64**

Req Band DL	CBD	Pedestrian	Vehicular	Cells/Group:
HIMM	1.76	21.36	0.59	23.70
HMM	11.43	70.86	4.57	86.86
MMM	3.95	75.48	0.88	80.31
SD	0.88	19.68	0.29	20.85
SM	0.06	0.45	0.05	0.56
S	9.57	70.27	1.44	81.27
Sum	27.64	258.09	7.81	**293.55**

UL+DL	CBD	Pedestrian	Vehicular	Total
HIMM	3.51	42.72	1.17	47.40
HMM	11.87	72.17	4.86	88.91
MMM	4.24	78.26	1.02	83.53
SD	1.76	39.35	0.59	41.69
SM	0.13	0.90	0.10	1.12
S	19.13	140.54	2.87	162.55
Sum	40.64	373.94	10.61	**425.19**

Calculation of Beta Factor for Guardbands, Spectrum Modularity, and Spectrum Inefficiencies of Multiple Networks

Number of Networks/Operators Considered	2
Trunking Factor of Multiple Networks	7.00%
Guardbands	4.00%
Beta factor before modularity	1.110

Applying the Guardband and Multiple Network component of Beta:

UPLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	146
DOWNLINK SPECTRUM REQUIREMENT BEFORE MODULARITY	326
Total Spectrum (Uplink +Downlink) before modularity	**472**

Applying the Modularity component of Beta for a 5 MHz minimum spectrum subdivision to give a multiple of 5 MHz boundaries for the division of spectrum across the separate networks/operators:

Number of Networks Considered =	2		
		diff uplink MHz=	3.9
Beta Modularity Component (applied to total spectrum)	1.70%	diff downlink MHz=	4.2
		diff total MHz=	8.0
TOTAL SPECTRUM REQUIREMENT (Uplink + Downlink)	**480**		

Breakdown by direction of transmission and modularity per network:

Uplink spectrum requirement after 5 MHz subdivision modularity	150	mod per network =	75.00 MHz
Downlink spectrum requirement after 5 MHz subdivision modularity	330	mod per network =	165.00 MHz

Note: This breakdown of the total requirement shows the asymmetry of required spectrum due to asymmetrical multimedia traffic flows in IMT-2000.

The modularity per network value gives the required spectrum for the selected number of networks on a per network basis for uplink and downlink.

APPENDIX 3

TO ANNEX 1

The United States of America's forecasting of IMT-2000 satellite users and traffic

1 Introduction

This Appendix is in response to the request by Radiocommunication Task Group (TG) 8/1 for a detailed market forecast of global satellite demand for IMT-2000. As noted by the TG, such a forecast is critical in assessing spectrum requirements for MSS IMT-2000 services in the 2005-2010 time-frame. The current spectrum allocation for these services is 1 980-2 010 (uplink); 2 170-2 200 (downlink), 2 010-2 025 (uplink – Region 2 only), and 2 160-2 170 (downlink – Region 2 only). This Appendix addresses five key areas:

– *Overview*: summary of forecast methodology, sources and sensitivities.

– *Market size*: IMT-2000 subscribers to MSS services.

– *Service definitions*: IMT-2000 services offered over MSS.

– *Usage levels*: IMT-2000 usage forecast for MSS.

– *Traffic parameters*: busy hour, busy hour offset, geographical peaking factor.

2 Overview

Deriving a detailed 2005-2010 global forecast for subscribers and usage of IMT-2000 involves all of the known obstacles of forecasting, plus the added difficulty of anticipating subscriber behaviour vis-à-vis completely new services. That said, it should be noted that this forecast is based on the most thorough analysis of the current and projected marketplace available at this time, with sources ranging from primary research to in-depth studies of secondary data.

The subscriber forecast is derived from primary market research on the number of cellular users who expressed interest in extremely high-end MSS services. These users tend to be early adopters of new technology, with high expectations for service quality. The service descriptions for IMT-2000 are based on secondary research and analysis of the types of services that are most appropriate for this particular segment of the marketplace. Finally, the usage level forecast is based on a combination of primary research and secondary analysis. Further detail on methodology (see Figs. 3 through 5) will be provided in each section below.

The overall forecast for annual traffic is most sensitive to changes in anticipated voice and data usage trends and less sensitive to marginal shifts in subscriber counts. Given that usage – particularly data usage – is difficult to predict, some range accommodation is necessary in the forecast methodology. Conservative assumptions are used on all fronts, with the final output being a range of traffic for the 2005 and 2010 time-frame. For the final calculation, the high end of the range is considered the most likely scenario, though even that is considered conservative.

3 Market size and profile

Second generation MSS services will complement and extend the terrestrial wireless launch of IMT-2000. As such, its subscriber base is a subset of cellular subscribers (less than 2%) in this time-frame. The profile of this niche includes primarily business people who travel to or reside in areas outside of traditional terrestrial wireless coverage (see Note 1). At the top tier of the marketplace, they have high expectations for quality, high communication needs, and extremely high usage levels. As such, they are attracted to the wide variety of service offerings provided by IMT-2000, which will be discussed in the next section.

As noted above, the subscriber forecast is derived from primary market research. This research has employed multiple independent surveys in the marketplace, designed to ensure valid and consistent respondent results. The research shows that the market for very high-end MSS services will reach 12 million subscribers in 2005 (see Note 2). Using a conservative compound annual growth rate of 15% (see Note 3), this market will climb to over 23 million users in 2010.

NOTE 1 – This forecast focuses on projected MSS subscribers in 2005 who choose to upgrade to IMT-2000 services. It does not include the additional potential market of cellular subscribers who live outside of 3G coverage and who might subscribe to MSS services to obtain the IMT-2000 enhanced service offering.

NOTE 2 – This forecast is just for MSS subscribers interested in high-end IMT-2000 services. According to Bear, Stearns and Co. Inc., the total market for MSS subscribers will be approximately 26 million users in 2005. This suggests that 46% of all MSS subscribers will be interested in enhanced services, compared to 15% of all cellular subscribers (according to UMTS Forum Report, Spectrum for IMT-2000 and Analyses Study, UMTS Market Forecast Study). As expected, the MSS percentage is higher, given that the satellite market consists of already high-end users.

NOTE 3 – This growth rate is benmarked against projected cellular growth trends

FIGURE 3

Methodology to forecast MSS IMT-2000 traffic

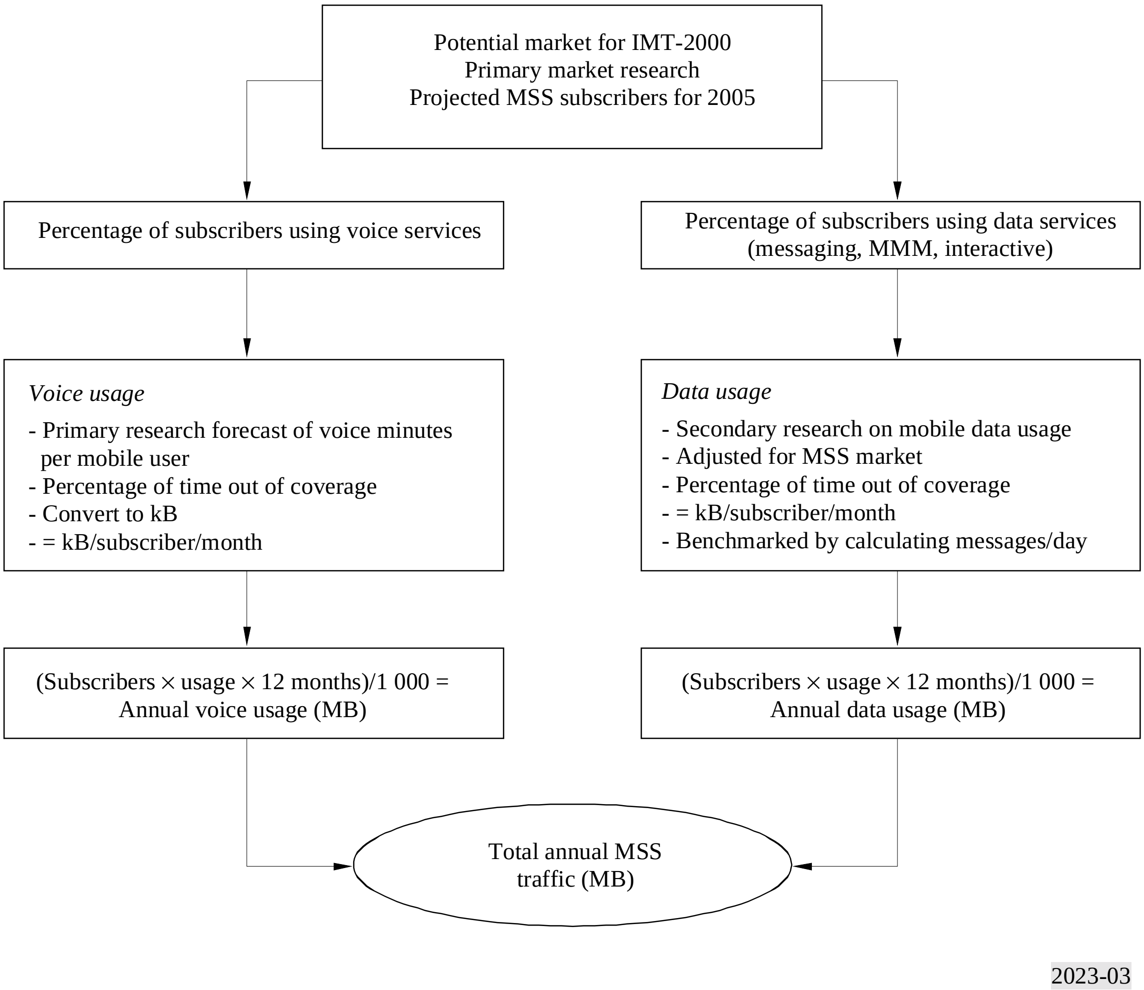
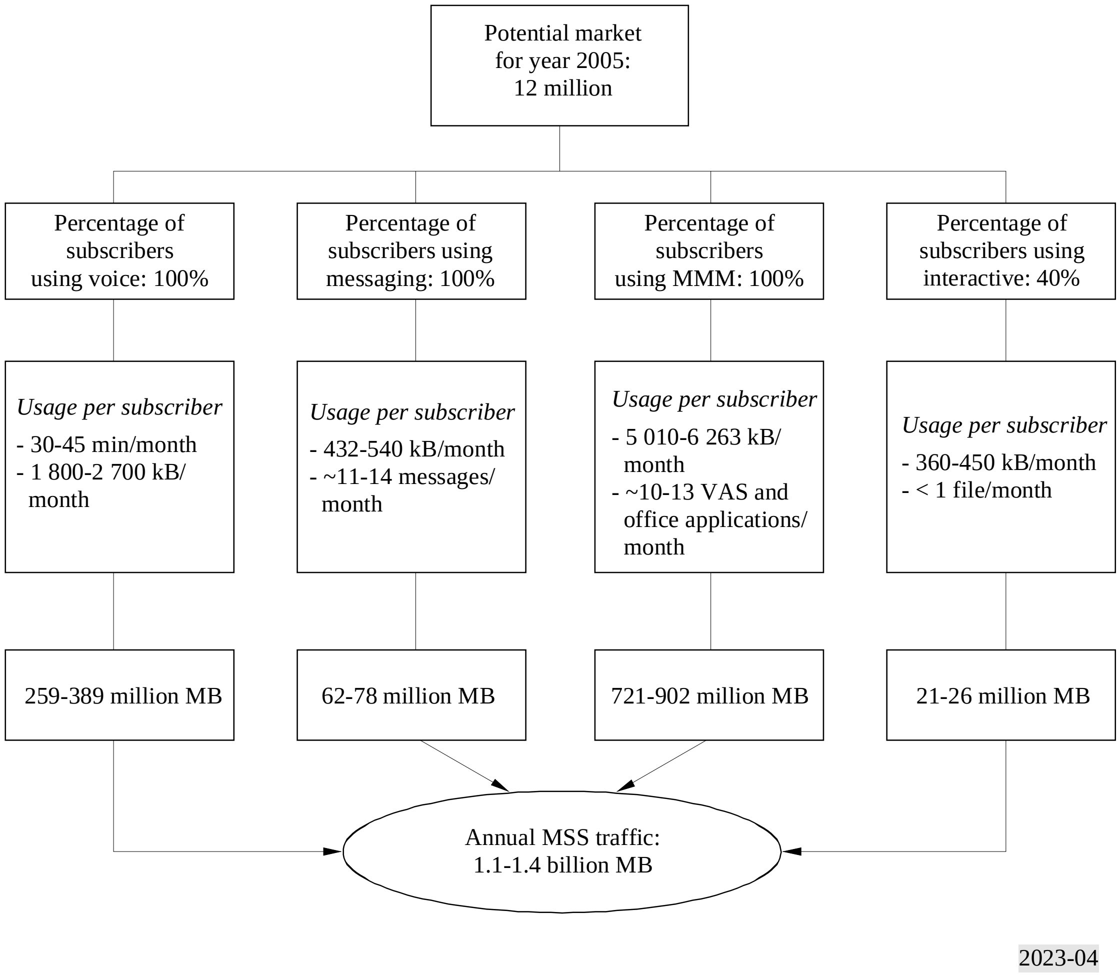


FIGURE 4

MSS IMT-2000 forecast traffic for year 2005



4 Service definition

As noted earlier, IMT-2000 MSS services will largely be an extension of terrestrial wireless 3G services and capabilities, with certain modifications designed to meet the specific needs of the MSS user described above. All services described here are for the mobile user, relying on services delivered through the handset or a handset-laptop combination. Fixed alternatives, such as those anticipated by the FSS, do not meet the needs of the mobile user profiled above. The service descriptions below are consistent with the concepts expressed in Recommendation ITU-R M.816.

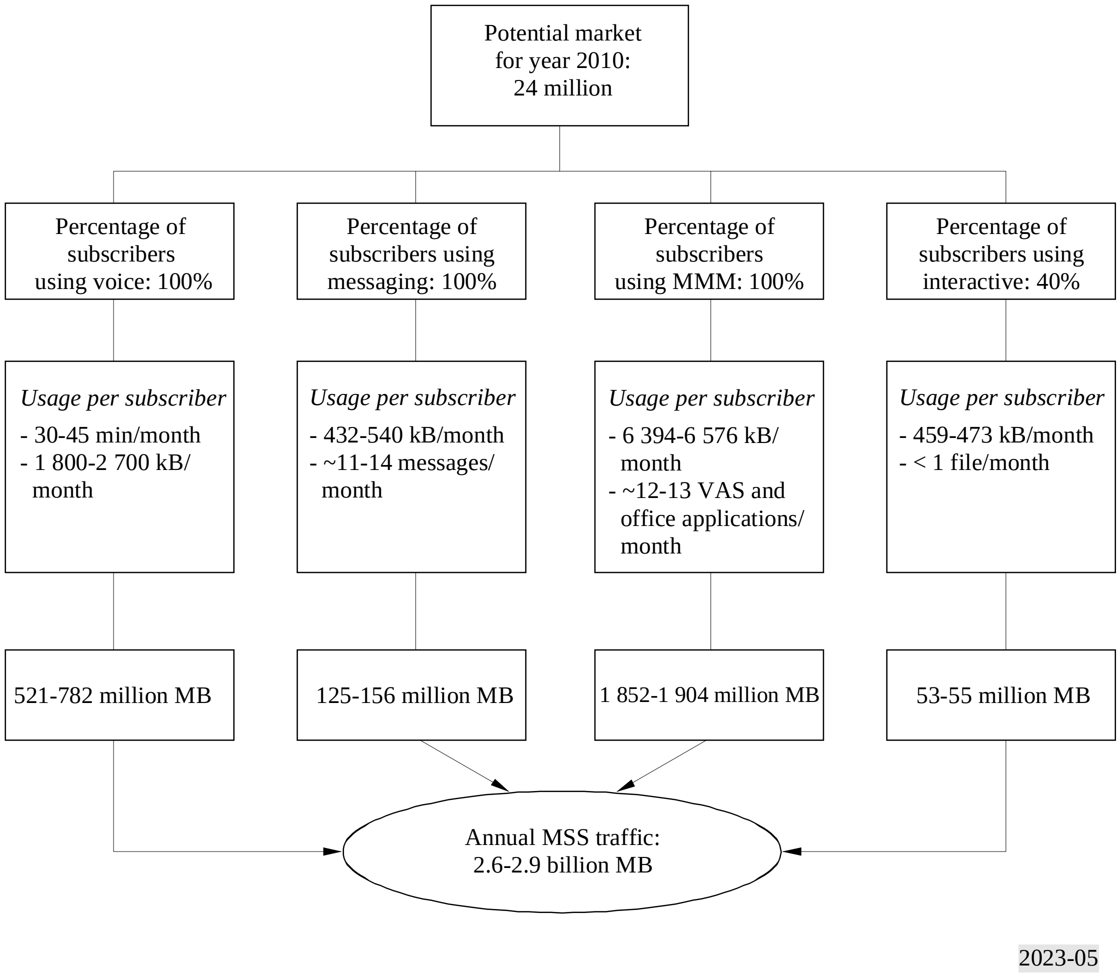
There are four broad categories of services in the IMT-2000 offering, ranging in transmission speed from 4 kbit/s to 384 kbit/s: voice, messaging, MMM services, and HIMM services. Multimedia data at 2 Mbit/s is excluded from this discussion, as it is not expected to be provided as a mobile service offering by MSS operators. The offered services are defined below, with examples of key applications for the MSS market that will drive usage levels.

Voice Services**:** Voice services will not differ significantly from what is available over some enhanced cellular offerings today. MSS operators will likely provide voice services at a rate of 8 to 16 kbit/s, meeting expectations for toll-quality transmission. (Calculations in this text are based on an assumed voice rate of 8 kbit/s.)

Messaging services**:** Defined to include both SMS, paging, and email, messaging services will not differ dramatically in concept from those available over terrestrial wireless today. However, MSS quality will be enhanced to include extended message length, better delivery rates, and two-way paging. File length will range between 10 kbit/s to 40 kbit/s. (As reported by Analysys, UMTS Market Forecast, and UMTS Forum, Spectrum for IMT-2000, p. 21.)

FIGURE 5

MSS IMT-2000 forecast traffic for year 2010



***MMM services*:** Services that will differ most from those available today are data and multimedia services. Defined as asymmetric and bursty in nature, MMM services will require relatively high transmission capabilities (up to 144 kbit/s), with typical file sizes averaging 500 kbit/s. While a wide variety of services and applications will evolve to fill these channels, they can be simplified for the purposes of these discussions into two broad categories, both of which serve as productivity tools, for the MSS market: value-added mobile services, and remote office capabilities. These examples are provided with the primary objective of understanding the usage levels (discussed in following paragraphs).

Value-added mobile services (*VAS*)*:* VAS mobile are information services designed uniquely for the mobile market. In other words, the true value is not in receiving the same information you might request while at your desk, but rather in accessing information critical to your mobile status. Such services would include the ability to review flight/train schedule databases, request and receive maps/directions, book accommodations, access information on a company you are about to visit, etc. These services are generally asymmetrical, and can be accessed by request or by push technology. In general, the uplink request for information would be relatively small, while the downlink return of information could be significantly larger, particularly in the case of a map or other image-based data. By providing these services at a relatively high transmission speed, users will appreciate their efficiency and will rely on their handsets as integral travel tools.

Remote office services: The second key category is remote office productivity capabilities. Here the network is providing primarily the transmission mechanism, with occasional added value. The 144 kbit/s pipe will permit users to attach their handset to a laptop to transfer files to/from the office, access corporate intranets/databases, and download presentations. In other words, mobile professionals will become as dependent on soft data on the road as they are in the office today, with most of their files and information databases stored electronically. High memory servers will permit these files to be accessed from wherever an employee is travelling. In addition, IMT-2000 services also will enable the management of encrypted financial transactions and electronic commerce. Subscribers will be able to charge purchases via their handset, and expenses will be filed electronically while out of the office.

HIMM services**:** As suggested by the name, HIMM services are symmetric applications requiring continuous high-speed connections. The key applications that will take advantage of these transmission capabilities in the MSS arena are referred to as enhanced communication services. Enhanced communication capabilities include image and video-conferencing, tele-presentations, and visuals for remote diagnosis and repair. These types of services will require the highest available speeds (up to 384 kbit/s) (see Note 1) and will be used when an in-person presence is not possible or not practical. Only 40% of total MSS subscribers are expected to take advantage of these services.

In addition to the services described above, there will undoubtedly be a wide array of entertainment services that will be developed, supported, and used over MSS, including sports news, video downloads, and gaming. The drivers, however, for the high-end MSS subscriber are expected to be the productivity tools described above. Indeed, the applications supported by the services above will become as critical as voice accessibility over time, suggesting an ever increasing share of overall traffic (in bits) attributable to data.

NOTE 1 – IMT-2000 specifications recommend providing a user with up to 144 kbit/s while mobile, and up to 2 Mbit/s while fixed. As with some terrestrial wireless operators, however, satellite providers may choose to offer higher rates (up to 384 kbit/s) to mobile subscribers.

5 Usage calculations

The usage levels for the services described above are based on a combination of primary market research and secondary market analysis. MSS usage levels are provided in Mbit/s per month and year for each of four service categories: voice, messaging, MMM, and high-speed interactive services. Unlike the terrestrial wireless methodology, it was not necessary to differentiate usage levels by environment and mobility (see Note 1).

All MSS usage presented here is based on assumptions regarding the amount of time subscribers spend outside of terrestrial wireless coverage areas. All MSS *voice and messaging* usage occurs in areas where there is no digital cellular service at all. MSS *data services* usage occurs in areas where there is no enhanced 2nd generation or 3rd generation cellular service (see Note 2). It should be noted that, by definition, MSS subscribers typically spend a significant amount of time *in* or *transiting* through areas with inadequate traditional wireless coverage. The percent of time outside of coverage varies across subscriber type, lower for the business traveller and higher for journalists and other remote industrial workers.

Usage per subscriber stays static for voice and messaging over time, given the history of these applications in the marketplace and the stability of user requirements in this regard by 2005. By contrast, usage per subscriber of MMM (VAS, remote office applications) and interactive high-speed data (enhanced communication services) can be expected to increase at an annual rate of 5% between 2005 and 2010, as subscribers become increasingly dependent on the value provided by these services.

Voice**:** Voice communications levels for the high-end MSS subscriber are anticipated to be approximately 1.8 to 2.7 Mbit/s per month. This is based on primary research regarding reported and validated usage habits, which were then integrated with the subscribers' travel profile and time spent outside of terrestrial wireless coverage (see Note 3). Voice usage per subscriber remains constant over time in the model provided here. It is assumed that high-end users are familiar with the benefits of wireless communications and their voice usage profile will not change with the introduction of IMT-2000's high quality voice services.

Simple messaging**:** SMS messaging and paging usage are expected to be high for several reasons. First, messaging is expected to become the email of the future, experiencing the same type of exponential growth over the next few years as wireline email. Nearly 3 trillion email messages were generated in the United States of America alone in 1997, and that number is expected to double by the turn of the century (Willkofsky Gruen Associates, as presented by MMTA). Not only will mobile subscribers forward wireline email to their phones and pagers while travelling, but the generation of mobile messages also will grow. Subscribers to MSS are expected to send and receive a total of 9 to 14 messages while outside of terrestrial coverage. With an average message length of 40 kbit/s, this translates into 360 to 540 kbit/s per month per subscriber (see Note 4). As with voice, the number of messages per subscriber is not expected to grow significantly between 2005 and 2010. Indeed, most of the growth in this area will occur between now and 2003, as mobile users experiment with the most effective way to manage their unified mailboxes.

MMM services**:** Secondary research (See Analysys, UMTS Market Report, figures for Medium Multimedia and Switched Data services.), adjusted for the MSS market and time spent outside of terrestrial wireless coverage, suggests that MSS subscribers will use an estimated 4 200 to 6 300 kbit/s of MMM services per month (see Note 5). With an average file size of 500 kbit/s, this translates to 8 to 13 files per month over the satellite system for VAS and remote office applications combined. This figure is expected to increase over time (5% per year), as subscribers become increasingly dependent on the tools. This usage is divided as follows:

VAS: The VAS will, in many ways, mimic the growth of information demands and data requests in the office and, as such, can be expected to account for a growing percentage of total mobile traffic. Monthly usage will include pushed information (such as morning news files/images) and pulled information, such as maps or company statistics. Averaging across the different types of files, each transfer is expected to account for up to 500 kbit/s of data (see Note 6). Subscribers are expected to take advantage of at least 6 VAS service opportunities per month.

Remote office applications: Second only to voice calls in terms of importance to the subscriber, these capabilities are expected to dominate the traffic patterns of mobile professionals (see Note 7). File size is expected to average half a megabyte across the many applications, with subscribers sending or receiving an average anywhere from 2 to 7 files or downloads per month.

High-speed interactive data**:** The forecast for usage of this category is particularly difficult, given that it offers among the most advanced IMT-2000 services that will be supported over MSS. Relying again on secondary research, adjusted for the MSS market and the percent of time spent outside of coverage, usage is expected to be 300 to 450 kbit/s per subscriber per month in 2005. This usage is expected to increase at the same rate (5%) as other data services over IMT-2000.

NOTE 1 – The terrestrial wireless forecast requires this categorization to differentiate among cell size variations for different density areas (e.g., CBD vs. suburban) and fixed vs. mobile offerings (e.g., 2 Mbit/s in building). This is not necessary for MSS, since beam sizes do not vary and all services are considered mobile.

NOTE 2 – IMT-2000 services are expected to be backwards compatible with most 2nd generation cellular services, but not necessarily with lst generation. Based on this, it is expected that MSS voice and messaging usage will occur only in areas where there is either no cellular coverage or only analogue cellular. Similarly, MSS data usage will occur in areas where there are neither enhanced 2nd-generation cellular nor 3rd generation capabilities.

NOTE 3 – Substantial research has been done to analyse business subscriber travel patterns relative to terrestrial wireless coverage and build-out plans. However, given that this forecast is for all MSS providers, including those serving the industrial and rural markets, the percentage of time outside of cellular has been revised upwards slightly.

NOTE 4 – Message length based on UMTS Forum, Spectrum for IMT-2000, p. 21. This forecast does not take into account messages generated by stand-alone paging subscribers.

NOTE 5 – Without research on the anticipated coverage of enhanced 2nd generation and 3rd generation systems, the same percentages for outside coverage are used for MMM and HIMM as were used for voice and messaging. This is very conservative for the 2005 time-frame, as the percentages are likely much higher.

NOTE 6 – Note that some of this information could be transmitted in smaller file formats, such as providing just the written instructions without the map, or just the company statistics, without the picture of the CEO. However, the competitive advantage offered by IMT-2000 is the capability to provide the extra utility demanded by this niche segment of the market.

NOTE 7 – Research conducted by the Mobile Data Initiative shows that mobile professionals currently account for 19% to 23% of the total workforce, and this number is expected to increase.

6 Traffic characteristics

MSS traffic mimics terrestrial cellular in many of its characteristics, though there are some unique attributes relative to busy hour, busy hour offset, geographical distribution, and peaking factors, that need to be discussed here.

– *Busy hour:* The busy hour for terrestrial wireless services is driven by usage of home-based subscribers. By contrast, MSS subscribers are primarily travellers who are roaming between or beyond traditional coverage areas. As such, their *voice traffic patterns* are based not on their home business hours, nor on the business hours of their destination, but rather on the overlap of these two regions' business hours. In other words, a United States of America's subscriber travelling in a remote area of Japan would typically make an MSS call during waking hours for both the United States of America and Japan. This overlap phenomenon has the effect of flattening the overall time of day/usage curve slightly. Based on this analysis, the percent of the total daily voice traffic occurring in the busy hour is projected at 10%. By contrast, *data usage* (including messaging) is not restricted to the overlap of the home and visited curve, since Intranet queries and VAS do not require a live person at the other end. Therefore, this traffic is more likely to peak during business hours of the visited location, with about 15% of the total traffic during the busiest hour.

– *Busy hour offset factor:* Because MSS services are focused primarily on the business/industrial user, the busy hour offset factor is low. There is no non-business vs. business busy hour to take into consideration.

– *Geographical distribution:* Global MSS systems experience different levels of traffic around the globe. The tables attached to this document show both worldwide demand and regional expectations.

– *Peaking factor:* Unlike terrestrial wireless calculations that occur on a localized basis, MSS services are global in nature. Even when just a single region is analysed (e.g., the United States of America), the traffic is not evenly distributed over that area. Therefore, just as busy hour traffic must be considered, so too must busy region traffic. The peaking factor is dependent on population density and is likely in the range of 3:1 up to 5:1.

MSS IMT-2000 Annual traffic – Worldwide (Millions of MB)		
	2005	2010
Voice	259-389	521-782
Messaging	62-78	125-156
MMM	721-902	1 852-1 904
HIMM	21-26	53-55
Total	**1 063-1 395**	**2 551-2 897**

MSS IMT-2000 Annual traffic – By Region (Millions of MB)		
	2005	2010
North and South America	298-390	714-811
Japan/Pacific Rim	245-321	587-666
Western Europe	43-56	102-116
Eastern Europe and Eurasia	181-237	434-493
Middle East/Africa	298-391	714-811
Total	**1 063-1 395**	**2 551-2 897**

APPENDIX 4

TO ANNEX 1

Satellite component spectrum calculations based on the United States of America's forecasts

1 Introduction

This Appendix presents calculations of the spectrum requirements for the satellite component of IMT-2000 based on the market forecasts given in Appendix 2 to Annex 1. Please refer to Appendix 2 to Annex 1 for description of the service types.

2 Calculations based on the United States of America's forecasts

2.1 Traffic inputs assumptions

The traffic figures given in Appendix 2 to Annex 1 are split into different geographical regions. For the purpose of the spectrum calculations these traffic inputs have been combined as follows: the traffic in the three regions Western Europe, Eastern Europe and Eurasia and Middle East/Africa was combined into Region 1 traffic, the traffic in North and South America was taken as Region 2 traffic and the traffic in Japan/Pacific Rim was taken as Region 3 traffic.

The size of a beam cluster was assumed to be 1.5 million km^2. It was assumed that 10% of the traffic in a particular Region will be concentrated in one beam cluster. This assumption may need further consideration, taking into account the size of the (land mass of) each Region and the traffic variations within the Regions.

2.2 Results

The results of the calculations for the MSS spectrum needed to support the satellite component of IMT-2000 are given below (Tables 21 to 26). The parameters listed in the Tables have the following meaning:

T: total traffic (millions of MB/year)

p: proportion of the diurnal traffic in the busy hour of the day

R: traffic in the overall busy hour (Mbit/s)

h: busy hour offset factor

R': traffic in the overall busy hour

b: number of beam clusters

d: delay factor

C: capacity per carrier (kbit/s)

n: number of carriers

W: carrier bandwidth (kHz)

F: required bandwidth (MHz).

Further expansion of these parameters can be found in Recommendation ITU-R M.1391.

Note that Tables 21 to 26 give the spectrum requirement in each direction.

TABLE 21

Spectrum needed to support IMT-2000 MSS requirements for Region 1 in 2005

	Voice	Message	MMM	HIMM	
T (Millions of MB)	19.1	1.9	22.1	1.3	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	11.61	1.75	20.20	1.16	
h	1	1	1	0.9	
R′ (Mbit/s)	11.61	1.75	20.20	1.05	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	80.64	6.06	70.12	7.28	
W (kHz)	200	200	200	200	
F (MHz)	16.13	1.21	14.02	1.46	*32.82*

TABLE 22

Spectrum needed to support IMT-2000 MSS requirements for Region 2 in 2005

	Voice	Message	MMM	HIMM	
T (Millions of MB)	10.9	1.1	12.6	0.7	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	6.62	1.00	11.51	0.66	
h	1	1	1	0.9	
R′ (Mbit/s)	6.62	1.00	11.51	0.60	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	45.98	3.46	39.98	4.15	
W (kHz)	200	200	200	200	
F (MHz)	9.20	0.69	8.00	0.83	*18.71*

TABLE 23

Spectrum needed to support IMT-2000 MSS requirements for Region 3 in 2005

	Voice	Message	MMM	HIMM	
T (Millions of MB)	9.0	0.9	10.4	0.6	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	5.45	0.82	9.48	0.55	
h	1	1	1	0.9	
R′ (Mbit/s)	5.45	0.82	9.48	0.49	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	37.85	2.85	32.91	3.41	
W (kHz)	200	200	200	200	
F (MHz)	7.57	0.57	6.58	0.68	*15.40*

TABLE 24

Spectrum needed to support IMT-2000 MSS requirements for Region 1 in 2010

	Voice	Message	MMM	HIMM	
T (Millions of MB)	38.3	3.8	46.7	2.7	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	23.34	3.49	42.62	2.46	
h	1	1	1	0.9	
R′ (Mbit/s)	23.34	3.49	42.62	2.22	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	162.06	12.12	147.97	15.39	
W (kHz)	200	200	200	200	
F (MHz)	32.41	2.42	29.59	3.08	*67.51*

TABLE 25

Spectrum needed to support IMT-2000 MSS requirements for Region 2 in 2010

	Voice	Message	MMM	HIMM	
T (Millions of MB)	21.9	2.2	26.7	1.5	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	13.33	1.99	24.34	1.41	
h	1	1	1	0.9	
R′ (Mbit/s)	13.33	1.99	24.34	1.27	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	92.56	6.92	84.51	8.79	
W (kHz)	200	200	200	200	
F (MHz)	18.51	1.38	16.90	1.76	*38.56*

TABLE 26

Spectrum needed to support IMT-2000 MSS requirements for Region 3 in 2010

	Voice	Message	MMM	HIMM	
T (Millions of MB)	18.0	1.8	21.9	1.30	
p	0.1	0.15	0.15	0.15	
R (Mbit/s)	10.95	1.64	19.99	1.15	
h	1	1	1	0.9	
R′ (Mbit/s)	10.95	1.64	19.99	1.04	
b	1	1	1	1	
d	1	2	2	1	
C (kbit/s)	144	144	144	144	
n	76.01	5.69	69.40	7.22	
W (kHz)	200	200	200	200	
F (MHz)	15.20	1.14	13.88	1.44	*31.66*

APPENDIX 5

TO ANNEX 1

Inmarsat's forecasting of MSS and IMT-2000 satellite users and traffic

1 Introduction

The UMTS Forum (Europe's initiative for IMT-2000 type services), through the Market Aspects Group, has forecast the demand for MSS (and the portion UMTS/IMT-2000 compliant) services for 2005 and 2010. These forecasts, adopted by the Forum, were largely based on Inmarsat's forecasts of the UMTS/IMT-2000 and MSS market. These forecasts were then used as a basis for the derivation of UMTS spectrum requirements for the satellite component of UMTS and MSS.

This Appendix details the methodology and approach used by Inmarsat to determine forecasts for MSS and IMT-2000 satellite-based services and the resultant forecasts. The UMTS Forum adopted global MSS/UMTS forecasts based on this methodology in 1997. Further work completed since then has determined a more robust methodology which results in differing user and traffic mix but does not result in significantly differing total traffic forecasts than those adopted by the UMTS Forum. This updated methodology and these forecasts are the ones included in this Appendix.

2 Overview

One objective of the IMT-2000 vision is to extend IMT-2000 services universally to all locations in which users may be personally mobile. Studies have shown that users will demand services in all locations and environments to which they travel or roam. As terrestrial IMT-2000 infrastructure is not expected to be able to offer services in all environments or geographical locations, due to speed of roll-out and economics, then users, in such areas, will be able to be satisfied by IMT-2000 services via satellite. Satellite IMT-2000 services will be offered in all geographic locations immediately from day one of IMT-2000 introduction.

Demand for IMT-2000 satellite services will largely be driven by the expectations created by terrestrial IMT-2000 services (i.e. users of IMT-2000 services will expect services to be available in all areas in which they are mobile). It is not expected that satellite IMT-2000 users will constitute a mass market in themselves.

Environments in which satellites will need to provide IMT-2000 services include:

– rural vehicular (e.g. trains, cars), pedestrian (mobile or portable) and fixed (semi-fixed non-permanent);

– remote vehicular, pedestrian and fixed;

– maritime (e.g. ships, boats) and aeronautical (e.g. planes);

– localized base stations (e.g. on trains or buses);

– any other locations where terrestrial IMT-2000 services are not yet available.

3 Market sizing

The trend in personal communications is towards ever smaller terminal size and portability. However, the inevitable mismatch between size and technical limitations leads to users being prepared to accept some trade-offs between size/portability and functionality/capability. It is likely that IMT-2000 services delivered via satellite will fall into two differing terminal types. One will provide services limited to voice and low speed data but incorporating dual mode (terrestrial/satellite) into a hand-held terminal. The other will provide full IMT-2000 multimedia services to the minimum wide-area data rates but with a slightly less portable terminal then a hand-held (which will also be capable of acting as a base station providing hand-held services in a localised area). In the case of dual mode handsets, the IMT-2000 network will search first for a terrestrial signal and if this is not available, then it will automatically switch to satellite.

Forecasts for MSS and IMT-2000 subscribers have been segmented into non-multimedia subscribers (those requiring non-multimedia services only) and multimedia subscribers (which in turn have been segmented into frequent and less-frequent users). It is expected that all the forecast multimedia subscribers will be IMT-2000 compliant while only a portion of the non-multimedia subscribers will be IMT-2000 compliant.

The forecasts for non-multimedia subscribers have been based largely on previous primary and secondary research and a number of industry quoted forecasts for non-multimedia satellite-based services. The multimedia forecasts have been based on substantial primary and secondary research into both the size of the market and usage profiles.

Forecasts are as follows:

TABLE 27

Subscribers (000s)	*2005*	*2010*
Non multimedia	4 875	7 500
Multimedia	6 585	10 975

For multimedia users, frequent users will comprise 10% to 20% of the overall forecast users with infrequent users comprising the balance. Frequent users can best be described as spending the majority of their time outside terrestrial mobile coverage using satellite-based services as a core part of their day-to-day communication requirements. Infrequent users are those who would predominantly be terrestrial mobile users, however requiring similar services whilst temporarily out of coverage of terrestrial mobile systems.

4 Services and usage

For non-multimedia users, services extend only to basic voice services (but at high quality - 8/16 kbit/s) and low speed data (9.6/16 kbit/s). For multimedia users the requirements are for a variety of different services and applications. These are described below:

– *Voice*: quality basic voice at 8/16 kbit/s.

– *Low speed data*: predominantly messaging and email (without attachments) type services at 9.6/16 kbit/s.

– *Asymmetric services*: this includes the predominantly one-way services including file transfer, database/LAN access, Intranet/Internet, WWW, email (with attachments), image transfer, etc. Rates of transmission will be up to and around 144 kbit/s. This corresponds to the medium (and high) multimedia services as defined by UMTS and wide area rates defined by UMTS and IMT-2000.

– *Interactive multimedia*: predominantly relating to videoconferencing and videotelephony at data speeds of around 144 kbit/s. This corresponds to the HIMM services as defined by UMTS and wide area rates defined by UMTS and IMT-2000.

Primary research studies have shown that the asymmetric services are the most demanded by users requiring IMT-2000 type services via satellite. This is not significantly different from terrestrial requirements, however the requirement for HIMM will be more than with satellite.

Forecasts for utilization of these services have been based on current company experience (as an MSS operator today), primary research of user profiles, secondary research and inputs from IT companies regarding multimedia applications.

The usage levels shown in Table 28 are represented in either min or both Mbit/s (MB) per month depending on service type. Two-way services such as voice and interactive multimedia are most likely to be priced per minute (taking into account quality based on data rate) whereas (predominantly) one-way services such as low-speed data and asymmetric services would be priced per volume of data (taking into account data speeds as well).

TABLE 28

Forecast usage levels for mobile-satellite services

Average usage per month	*Basis*	*2005*	*2010*
Non-multimedia			
Voice	min at kbit/s	73	71
Low speed data	kBs	8 365	8 175 equates to ~ 70 min/month at 16 kbit/s
Multimedia			
Voice	min at 8 kbit/s	20	26
Low speed data	kBs	2 584	3 380 equates to ~ 25 min/month at 16 kbit/s
Asymmetric	kBs	26 154	34 247 equates to ~ 35 min/month at 104/144 kbit/s
Interactive	min at 144 kbit/s	2	2 average low due to the fact that only a small portion (10% to 20%) of forecasted users will use interactive service

The average usage is based on a combination of frequent and infrequent users. For example, with asymmetric services, frequent users will have usage exceeding 100 min/month whereas infrequent users would have usage levels in the order of 10% to 20 min/month. In addition, the forecast usage represents one direction only, i.e. there will be the same requirement in both directions.

Based on the usage profiles the total traffic forecasts (for MSS) are as shown in Table 29.

TABLEAU 29

Total mobile-satellite traffic forecasts

Traffic (millions MBs)		
Non-multimedia		
Voice	509	764
Low speed data	491	736
	1 000	1 500
Multimedia		
Voice	94	206
Low speed data	204	445
Asymmetric	2 067	4 510
Interactive	141	307
	2 506	5 468
Total	3 506	6 968

IMT-2000 traffic forecasts exclude that traffic which is not IMT-2000 compliant. Non-IMT-2000 compliant traffic is predominantly represented by 1st and 2nd generation basic voice and low speed data services. Thus the forecast IMT-2000 traffic is as shown in Table 30.

TABLE 30

Satellite IMT-2000 traffic forecasts

Traffic (million MBs)		
Non-multimedia		
Voice	34	123
Low speed data	33	119
	67	242
Multimedia		
Voice	94	206
Low speed data	204	445
Asymmetric	2 067	4 510
Interactive	141	307
	2 506	5 468
Total	2 573	5 710

APPENDIX 6

TO ANNEX 1

Satellite component spectrum calculations based on the Inmarsat forecasts

1 Introduction

This Appendix presents calculations of the spectrum requirements for the satellite component of IMT-2000 and MSS based on the market forecasts given in Appendix 4 to Annex 1. Please refer to Appendix 4 to Annex 1 for description of the service types.

2 Calculations based on the Inmarsat forecasts

2.1 Results

The spectrum calculations are given below (see Tables 31 to 36) with a discussion of the various parameters following that. The parameters listed in the Tables have the following meaning:

- T: total traffic (millions of MB/year)
- p: proportion of the diurnal traffic in the busy hour of the day
- R: traffic in the overall busy hour (Mbit/s)
- h: busy hour offset factor
- R': traffic in the overall busy hour
- b: number of beam clusters
- d: delay factor
- C: capacity per carrier (kbit/s)
- n: number of carriers
- W: carrier bandwidth (kHz)
- F: required bandwidth (MHz).

Note that Tables 31 to 36 gives the spectrum requirement in each direction.

TABLE 31

Non-multimedia non-IMT-2000 traffic in 2005

Service type	Voice	Low speed data	
Total traffic (millions of Mbit/s)	475	458	
Percentage in hot spot	12	12	
T (millions of MB)	57	54.96	
p	0.15	0.15	
R (Mbit/s)	52.05	50.19	
h	87%	86%	
R' (Mbit/s)	45,21	43,24	
b	1	1	
d	1	2	
C (kbit/s)	144	144	
n	313.99	150.14	
W (kHz)	200	200	
F (MHz)	62.80	30.03	*92.83*

TABLE 32

Non-multimedia IMT-2000 traffic in 2005

Service type	Voice	Low speed data	
Total traffic (millions of Mbit/s)	34	33	
Percentage in hot spot	12	12	
T (millions of MB)	4.08	3.96	
p	0.15	0.15	
R (Mbit/s)	3.73	3.62	
h	87%	86%	
R′ (Mbit/s)	3.24	3.12	
b	2	2	
d	1	2	
C (kbit/s)	144	144	
n	11.24	5.41	
W (kHz)	200	200	
F (MHz)	2.25	1.08	*3.33*

TABLE 33

Multimedia IMT-2000 traffic in 2005

Service type	Voice	Low speed data	Asymmetric	Interactive	
Total traffic (millions of Mbit/s)	94	204	2 067	141	
Percentage in hot spot	10	10	10	10	
T (millions of MB)	9.4	20.4	206.7	14.1	
p	0.1	0.1	0.1	0.1	
R (Mbit/s)	5.72	12.42	125.84	8.58	
h	84%	86%	84%	84%	
R′ (Mbit/s)	4.80	10.74	105.60	7.20	
b	2	2	2	2	
d	1	2	5	1	
C (kbit/s)	144	144	144	144	
n	16.68	18.64	73.34	25.01	
W (kHz)	200	200	200	200	
F (MHz)	3.34	3.73	14.67	5.00	*26.73*

TABLE 34

Non-multimedia non-IMT-2000 traffic in 2010

Service type	Voice	Low speed data	
Total traffic (millions of Mbit/s)	641	617	
Percentage in hot spot	12	12	
T (millions of MB)	76.92	74.04	
p	0.15	0.15	
R (Mbit/s)	70.25	67.62	
h	82%	81%	
R′ (Mbit/s)	57.56	54.93	
b	1.5	1.5	
d	1	2	
C (kbit/s)	144	144	
n	266.47	127.14	
W (kHz)	200	200	
F (MHz)	53.29	25.43	*78.72*

TABLE 35

Non-multimedia IMT-2000 traffic in 2010

Service type	Voice	Low speed data	
Total traffic (millions of Mbit/s)	123	119	
Percentage in hot spot	12	12	
T (millions of MB)	14.76	14.28	
p	0.15	0.15	
R (Mbit/s)	13.48	13.04	
h	82%	81%	
R′ (Mbit/s)	11.04	10.59	
b	2	2	
d	1	2	
C (kbit/s)	144	144	
n	38.35	18.39	
W (kHz)	200	200	
F (MHz)	7.67	3.68	*11.35*

TABLE 36

Multimedia IMT-2000 traffic in 2010

Service type	Voice	Low speed data	Asymmetric	Interactive	
Total traffic (millions of Mbit/s)	206	445	4510	307	
Percentage in hot spot	10	10	10	10	
T (millions of MB)	20.6	44.5	451	30.7	
p	0.1	0.1	0.1	0.1	
R (Mbit/s)	12.54	27.09	274.58	18.69	
h	79%	81%	79%	79%	
R′ (Mbit/s)	9.92	22.08	217.23	14.79	
b	2	2	2	2	
d	1	2	5	1	
C (kbit/s)	144	144	144	144	
n	34.45	38.33	150.85	51.34	
W (kHz)	200	200	200	200	
F (MHz)	6.89	7.67	30.17	10.27	*55.00*

2.2 Discussion of input parameters

Percentage in hot spot: The calculations have been carried out for a global hot spot, which is approximately 3 million km^2 in area. The percentage of traffic in the hot spot specifies the percentage of the total worldwide traffic which originates from this area as predicted by the market forecast.

Proportion of diurnal traffic in the busy hour, p: based on the market forecasts, this has been chosen as $p = 0.1$ for multimedia traffic and $p = 0.15$ for non-multimedia traffic.

The busy hour offset factor, h: this factor has been calculated by considering 12 different traffic environments and calculating the weighted average of the busy hour offset factors for these environments.

Number of beam clusters in the area, b: in choosing this value, it has been considered that already planned non IMT-2000 MSS systems would typically cover the area in question with 1 beam cluster or less. Future MSS systems are expected to provide improved reuse, however it is unlikely that any MSS systems will be able to provide more than two beam clusters in the area by 2010. For the purpose of these calculations, it has been assumed that IMT-2000 satellites will have two beam clusters in the area ($b = 2$). This corresponds to, for example, an average footprint of around 200 000 km^2 and a frequency reuse pattern of 7. This frequency reuse has not yet been achieved, but is expected to be possible in the planned IMT-2000 time-frame.

The choice of the factor *b* has been considered together with the choice of modulation efficiency, i.e. C/W, since neither can be improved without considering the effect on the other. For example, an improved modulation efficiency will require a higher carrier-to-noise ratio, leading to a degradation in reuse. Also, in determining these factors, it was considered that actual frequency reuse can never be perfect, due to geographical variations in traffic volume.

Delay factor, d: *d* = 1 for the circuit-switched voice and interactive services. Based on the market studies, for the packet-switched low-speed data and asymmetric services, *d* has been taken as 2 and 5 respectively.

The capacity per carrier *C*, is assumed to be 144 kbit/s.

The carrier bandwidth *W*, has been taken as 200 kHz.

The information bit rate of 144 kbit/s plus overhead of approximately 30 kbit/s is thus assumed to be accommodated in a carrier bandwidth of 200 kHz, which can be achieved for example by QPSK modulation with an FEC rate approximately 0.6.% in hot spot: specifies the proportion of the total worldwide traffic which originates from the global hot spot; the size of this area is approximately 3 million km^2.

2.3 Summary

The spectrum requirements are summarized in Table 37.

TABLE 37

Summary of estimated satellite IMT-2000/MSS spectrum requirements (MHz per direction of transmission)

	2005	2010
Non IMT-2000(1)		
– Non-multimedia	93	79
IMT-2000		
– Non multimedia	3	11
– Multimedia	27	55
Total IMT-2000	30	66
Total SMS	123	145

(1) It is assumed that all multimedia traffic will be IMT-2000 compatible.

ATTACHMENT 1

TO APPENDIX 6

Calculation of busy hour offset factors

Tables 38 and 39 show the projected traffic split and busy hour offset for each environment and service for the years 2005 and 2010 respectively. The Tables also show the resulting weighted average of the busy hour factor.

TABLE 38

Traffic split per environment and service and calculation of weighted busy hour factors, year 2005

Multimedia traffic in 2005	Percentage of traffic in each environment				Percentage of traffic in overall busy hour[1]	Split across environment			
	Voice	LSD	Asymmetric	Interactive		Voice	LSD	Asymmetric	Interactive
Rural pedestrian (hand-held, portable, transportable)	24%	24%	24%	24%	100%	24%	24%	24%	24%
Rural vehicular (Car, truck, train, bus)	6%	6%	6%	6%	100%	6%	6%	6%	6%
Rural semi-fixed	5%	5%	5%	5%	85%	4%	4%	4%	4%
Remote pedestrian	34%	35%	34%	34%	100%	34%	35%	34%	34%
Remote vehicular	6%	6%	6%	6%	100%	6%	6%	6%	6%
Remote semi-fixed	8%	9%	8%	8%	85%	7%	7%	7%	7%
Off-shore maritime (yacht, tug boat)[2]	2%	1%	2%	0%	0%	0%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)[2]	2%	1%	2%	2%	0%	0%	0%	0%	0%
Personal/Corporate aeronautical[3]	5%	5%	5%	5%	60%	1%	2%	1%	1%
Passenger aeronautical[3]	8%	8%	8%	8%	40%	2%	2%	2%	2%
Localised base-station[4]	0%	0%	0%	0%	0%	0%	0%	0%	0%
Terrestrial fill-in[4]	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	100%	100%	100%					
	Busy hour offset factor – Weighted average					84%	86%	84%	84%

Non-multimedia traffic in 2005	Percentage of traffic in each environment		Percentage of traffic in overall busy hour[1]	Split across environment	
	Voice	LSD		Voice	LSD
Rural pedestrian (hand-held, portable, transportable)	57%	58%	100%	57%	58%
Rural vehicular (Car, truck, train, bus)	2%	2%	100%	2%	2%
Rural semi-fixed	11%	11%	85%	9%	9%
Remote pedestrian	7%	5%	100%	7%	5%
Remote vehicular	4%	4%	100%	4%	4%
Remote semi-fixed	3%	4%	85%	3%	3%
Off-shore maritime (yacht, tug boat)[2]	1%	1%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)[2]	3%	3%	0%	0%	0%
Personal/Corporate aeronautical[3]	2%	2%	60%	1%	1%
Passenger aeronautical[3]	3%	3%	40%	1%	1%
Localised base-station	7%	8%	50%	4%	4%
Terrestrial fill-in[4]	0%	0%	0%	0%	0%
	100%	100%			
	Busy hour offset factor – Weighted average			87%	86%

LSD: Low speed data

(1) Includes both business and non-business.

(2) Maritime excluded from busy hour as traffic generated will never be in the hot spot.

(3) Aero traffic in busy hour halved.

(4) No traffic share for these environments included currently, however total foreacast traffic inlcudes these environments.

TABLE 39

Traffic split per environment and service and calculation of weighted busy hour factors, year 2010

200%

Multimedia traffic in 2010	Percentage of traffic in each environment				Percentage of traffic in overall busy hour[(1)]	Split across environment			
	Voice	LSD	Asymmetric	Interactive		Voice	LSD	Asymmetric	Interactive
Rural pedestrian (hand-held, portable, transportable)	24%	24%	24%	24%	95%	22%	23%	22%	22%
Rural vehicular (Car, truck, train, bus)	6%	6%	6%	6%	95%	6%	6%	6%	6%
Rural semi-fixed	5%	5%	5%	5%	75%	4%	4%	4%	4%
Remote pedestrian	34%	35%	34%	34%	95%	32%	33%	32%	32%
Remote vehicular	6%	6%	6%	6%	95%	6%	6%	6%	6%
Remote semi-fixed	8%	9%	8%	8%	75%	6%	7%	6%	6%
Off-shore maritime (yacht, tug boat)[(2)]	2%	1%	2%	2%	0%	0%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)[(2)]	2%	1%	2%	2%	0%	0%	0%	0%	0%
Personal/Corporate aeronautical[(3)]	5%	5%	5%	5%	60%	1%	2%	1%	1%
Passenger aeronautical[(3)]	8%	8%	8%	8%	40%	2%	2%	2%	2%
Localised base-station[(4)]	0%	0%	0%	0%	0%	0%	0%	0%	0%
Terrestrial fill-in[(4)]	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	100%	100%	100%					
	Busy hour offset factor – Weighted average					79%	81%	79%	79%

Non-multimedia traffic in 2010	Percentage of traffic in each environment		Percentage of traffic in overall busy hour[(1)]	Split across environment	
	Voice	LSD		Voice	LSD
Rural pedestrian (hand-held, portable, transportable)	57%	58%	95%	54%	55%
Rural vehicular (Car, truck, train, bus)	2%	2%	95%	2%	2%
Rural semi-fixed	11%	11%	75%	8%	8%
Remote pedestrian	7%	5%	95%	7%	5%
Remote vehicular	4%	4%	95%	4%	3%
Remote semi-fixed	3%	4%	75%	3%	3%
Off-shore maritime (yacht, tug boat)[(2)]	1%	1%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)[(2)]	3%	3%	0%	0%	0%
Personal/Corporate aeronautical[(3)]	2%	2%	60%	1%	1%
Passenger aeronautical[(3)]	3%	3%	40%	1%	1%
Localised base-station	7%	8%	50%	4%	4%
Terrestrial fill-in[(4)]	0%	0%	0%	0%	0%
	100%	100%			
	Busy hour offset factor – Weighted average			82%	81%

(1) Includes both business and non-business.

(2) Maritime excluded from busy hour as traffic generated will never be in the hot spot.

(3) Aero traffic in busy hour halved.

(4) No traffic share for these environments included currently, however total foreacast traffic inlcudes these environments.