



Recommendation ITU-R M.1768-1
(04/2013)

**Methodology for calculation of spectrum
requirements for the terrestrial component
of International Mobile Telecommunications**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**



International
Telecommunication
Union
Documents

Document Sharing Hub

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at <http://www.itu.int/publ/R-REC/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2013

© ITU 2013

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

RECOMMENDATION ITU-R M.1768-1

Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications

(2006-2013)

Scope

This Recommendation describes a methodology for the calculation of terrestrial spectrum requirement estimation for International Mobile Telecommunications (IMT).

It provides a systematic approach that incorporates service categories (a combination of service type and traffic class), service environments (a combination of service usage pattern and teledensity), radio environments, market data analysis and traffic estimation by using these categories and environments, traffic distribution among radio access technique groups (RATGs), required system capacity calculation and resultant spectrum requirement determination. The methodology is applicable to packet switch-based traffic and can accommodate multiple services. It can also accommodate circuit switched emulation traffic using a reservation based concept.

1 Related Recommendations and Reports

Recommendation ITU-R M.1390 –	<i>Methodology for the calculation of IMT-2000 terrestrial spectrum requirements.</i>
Recommendation ITU-R M.1457 –	<i>Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000).</i>
Recommendation ITU-R M.1645 –	<i>Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000.</i>
Recommendation ITU-R M.2012 –	<i>Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced).</i>
Report ITU-R M.2038 –	<i>Technology trends.</i>
Report ITU-R M.2072 –	<i>World mobile telecommunication market forecast.</i>
Report ITU-R M.2074 –	<i>Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000.</i>
Report ITU-R M.2243 –	<i>Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications.</i>

The ITU Radiocommunication Assembly,

considering

- a) that the radio access technique groups (RATGs) that are appropriate for IMT may have different channel bandwidth requirements, and hence varying impact on the basic frequency usage possibilities;
- b) that the methodology in Annex 1 is considered flexible enough to accommodate either a global view or the unique requirements of regional markets relative to terrestrial spectrum needs;
- c) that service functionalities in fixed, mobile and broadcasting networks are increasingly converging and interworking;

d) that the total telecommunication market will be provided by various communication means in terms of services and networks according to Recommendations ITU-R M.1645, ITU-R M.1457 and ITU-R M.2012;

dbis) that for the determination of spectrum requirements for IMT, new market requirements and network deployment scenarios have been developed and taken into account in Report ITU-R M.2243;

e) that other delivery mechanisms can support some user applications in common and convey their traffic;

f) that traffic distribution to those relevant other RATGs should be taken into account;

g) that Resolution 233 (WRC-12) invites ITU-R to study additional spectrum requirements for IMT;

h) that hence the spectrum requirement should be calculated only for the RATGs that fall in the IMT;

j) that a methodology for calculation of spectrum requirements for IMT should:

- i) accommodate the capabilities described in Recommendations ITU-R M.1645, ITU-R M.1457 and ITU-R M.2012;
- ii) accommodate the complex mixture of services that will require differing bandwidths and quality of service, and significantly higher bit rates than IMT-2000;
- iii) be able to model systems consisting of multiple interworking networks, and have the flexibility to handle different combinations of RSTGs in different environments and the possibility that the up and downlinks of a service may be provisioned on different radio access techniques RATs;
- iv) use market data which is practical to collect as input to the traffic forecasts;
- v) have the flexibility to handle both emerging technologies and enhancements to IMT;
- vi) take account of factors for practical network implementations;
- vii) produce results in a manner that is easily understandable and credible;
- viii) be implementable and verifiable within the available time-scales;
- ix) be suitable to be used during ITU-R meetings in terms of the computing facilities needed and the time required to perform an analysis;
- x) be no more complex than is justified by the uncertainty of the input data;
- xi) take into account improvements in spectrum efficiency due to the advances in technologies employed by enhancements to IMT,

recognizing

a) that the majority of the traffic has changed from speech-oriented communications to multimedia communications;

b) that networks and systems are designed to economically transfer packet data;

c) that services become more diverse and it will be less valid to consider simple peak traffic values that will apply across different environments, geographic areas and time,

recommends

1 that administrations wishing to estimate spectrum requirements for the terrestrial component of IMT use the methodology contained in Annex 1.

Annex 1

2.3 RATGs

The methodology takes into account the total terrestrial communication market that will be provided by various communication means in terms of services and networks according to Recommendations ITU-R M.1645, ITU-R M.1457 and ITU-R M.2012. There are a number of RATGs which can be identified. The present methodology distributes the total traffic forecasted for the total terrestrial communication market to the identified RATGs, which are:

Group 1: Pre-IMT systems, IMT-2000 and its enhancements.

This group covers the digital cellular mobile systems, IMT-2000 systems and their enhancements.

Group 2: IMT-Advanced systems as described in Recommendation ITU-R M.2012.

Group 3: Existing radio LANs and their enhancements.

Group 4: Digital mobile broadcasting systems and their enhancements.

3 The methodology for spectrum requirement calculations

3.1 Scope of the spectrum calculation methodology for IMT

The methodology considers traffic forecasts for all RATGs (RATG1-RATG4); however, it calculates spectrum requirements only for RATG1 and RATG2, which correspond to IMT systems.

3.2 Approach for spectrum calculation

The technical process of estimating spectrum requirements for mobile communications has to be based on four essential issues:

- Definition of services
- Market expectations
- Technical and operational framework
- Spectrum calculation algorithm.

3.3 Generic flow of the methodology

The generic flow chart for the spectrum requirement calculation methodology is shown in Fig. 1.

Step 1: presents the different definitions used in the methodology, which are given in § 3.4.

Step 2: analyses the market data, which may be obtained from Reports ITU-R M.2072 and ITU-R M.2243. Analysis of market data is described in § 3.5.

Step 3: values for the methodology are computed as described in § 3.5.2.6.

Step 4: distributes traffic to different RATGs and radio environments inside the RATGs, which is presented in § 3.6.

Step 5: determines required system capacity to carry the offered traffic. Capacity calculation algorithms are given separately for circuit switched and packet-switched service categories in §§ 4.1 and 4.2, respectively.

Step 6: calculates the spectrum requirements of RATG1 and RATG2 which is presented in § 4.3.

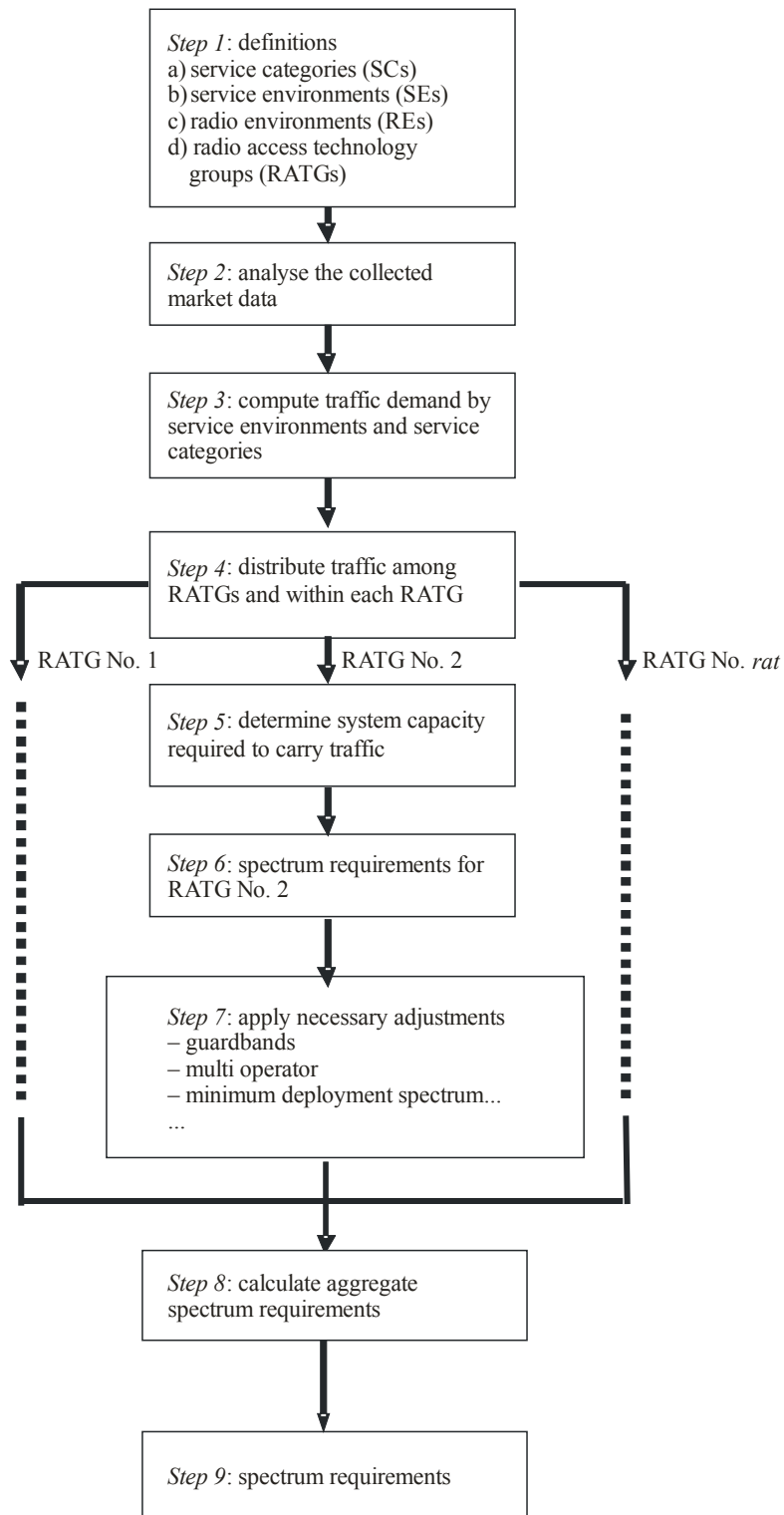
Step 7: applies necessary adjustments to take into account practical network deployments as described in § 5.

Step 8: calculates aggregate spectrum requirements in § 6.

Step 9: gives the spectrum requirements for RATG1 and RATG2 as an output.

FIGURE 1

Flow chart for a generic spectrum calculation methodology



M.1768-01

3.4 Definitions

In this section all the needed input parameters and associated categorizations are defined.

The following sections include tables for the required parameters for the methodology. The parameter values in these tables should be considered as examples as indicated in the corresponding tables.

First service types and traffic classes are introduced to reflect the likely peak data rates available and the likely traffic profile of a service. A service category is defined as a combination of the service type and traffic class.

Service environments are defined to categorize the area of where the user is when they are assessing a service and the traffic profile of that geographical area. Service environments are defined as a combination of service usage pattern and teledensity.

The radio environment is defined to reflect the radio infrastructure that provides the services to the users in service environment. Radio environments are defined to reflect the different radio deployments concepts.

Different RATGs are defined to take into account the wider terrestrial communication market available to provide the services.

3.4.1 Service categories

A service category (SC) is defined as a combination of service type and traffic class as shown in Table 1.

TABLE 1
Service categorization

Service type \ Traffic class	Conversational	Streaming	Interactive	Background
Super-high multimedia	SC1	SC6	SC11	SC16
High multimedia	SC2	SC7	SC12	SC17
Medium multimedia	SC3	SC8	SC13	SC18
Low rate data and low multimedia	SC4	SC9	SC14	SC19
Very low rate data ⁽¹⁾	SC5	SC10	SC15	SC20

⁽¹⁾ This includes speech and SMS.

3.4.1.1 Service types

The peak bit rates are used to categorize the service types. It is possible to group together services demanding similar data rates into a common category. The different services are divided into five service types as shown in Table 2.

TABLE 2
Service types and their peak bit rates

Service type	Peak bit rate
Very low rate data	< 16 kbit/s
Low rate data and low multimedia	< 144 kbit/s
Medium multimedia	< 2 Mbit/s
High multimedia	< 30 Mbit/s
Super-high multimedia	30 Mbit/s to 100 Mbit/s/1 Gbit/s

a) Very low rate data

This service type requires a peak bit rates up to 16 kbit/s. In the year 2010 onwards, there will be a demand for these very low data rate applications of speech and simple message service. In addition, some applications in the field of sensor communication and/or low bit rate data telemetry would also be expected to be in this category, as ubiquitous communications.

b) Low rate data and low multimedia

This service type supports data rates of up to 144 kbit/s. This service type takes into account of pre-IMT-2000 data communication applications.

c) Medium multimedia

This service type supports a peak bit rate of up to 2 Mbit/s. This type would be required to sustain the compatibility with the IMT-2000 applications.

d) High multimedia

This service type accommodates high data rate applications, including multimedia video streaming services, which are provided with xDSL service in fixed wired communication systems.

e) Super-high multimedia

This service type accommodates super-high data rates multimedia applications, which are currently provided with fibre-to-the-home (FTTH) services in case of wired communication systems.

3.4.1.2 Traffic classes

Methodology applies the traffic classes presented in Recommendation ITU-R M.1079, which defines four quality of service (QoS) classes for IMT-2000 from the user perspective:

- conversational class of service;
- interactive class of service;
- streaming class of service;
- background class of service.

The main distinguishing factor between these classes is how delay-sensitive the application is: conversational class refers to applications which are very delay-sensitive while background class is the most delay-insensitive QoS class.

For traffic classes based on Recommendation ITU-R M.1079 the conversational and streaming class are served with circuit switching and the background and interactive class with packet switching.

a) *Conversational class*

The most well-known use of this scheme is telephony speech. But with internet and multimedia a number of new applications will require this scheme, for example voice over Internet Protocol (VoIP) and videoconferencing tools. Real-time conversation is always performed between peers (or groups) of live (human) end users. The real-time conversation scheme is characterized by the transfer time that must be low because of:

- the conversational nature of the scheme;
- at the same time the time relation (variation) between information entities of the stream must be preserved in the same way as for real-time streams.

The maximum transfer delay is given by the human perception of video and audio conversation. Therefore the limit for acceptable transfer delay is very strict, as failure to provide low enough transfer delay will result in unacceptable lack of quality. The transfer delay requirement is therefore both significantly lower and more stringent than the round trip delay of interactive applications.

b) *Interactive class*

When the end-user, that is either a machine or a human, is online requesting data from remote equipment (e.g. a server) this scheme applies. Examples of human interaction with the remote equipment are: Web browsing, database retrieval, server access. Examples of machine interaction with remote equipment are: polling for measurement records and automatic database enquiries (tele-machines).

Interactive traffic is the other classical data communication scheme that on an overall level is characterized by the request response pattern of the end-user. At the message destination there is an entity expecting the message (response) within a certain time. Round-trip delay time is therefore one of the key attributes. Another characteristic is that the content of the packets must be transparently transferred (with low BER).

Interactive traffic – fundamental characteristics for QoS:

- request response pattern;
- preserve payload content.

c) *Streaming class*

When the user is looking at (listening to) real-time video (audio) the scheme of real-time streams applies. The real-time data flow is always aiming at a live (human) destination. It is a one-way transport.

This scheme is one of the newcomers in data communication, raising a number of new requirements in both telecommunication and data communication systems. It is characterized by the time relations (variation) between information entities (i.e. samples, packets) within a flow which must be preserved, although it does not have any requirements on low transfer delay.

The delay variation of the end-to-end flow must be limited, to preserve the time relation (variation) between information entities of the stream. But as the stream normally is time aligned at the receiving end (in the user equipment), the highest acceptable delay variation over the transmission media is given by the capability of the time alignment function of the application. Acceptable delay variation is thus much greater than the delay variation given by the limits of human perception.

Real-time streams – fundamental characteristics for QoS:

- unidirectional continuous stream;
- preserve time relation (variation) between information entities of the stream.

d) *Background class*

When the end-user, that typically is a computer, sends and receives data-files in the background, this scheme applies. Examples are background delivery of e-mails, SMS, download of databases and reception of measurement records.

Background traffic is one of the classical data communication schemes where an overall level is characterized by the absence of a parameter at the destination expecting to receive the data within a certain time limit, with the exception that there is still a delay constraint, since data is effectively useless if it is received too late for any practical purpose. The scheme is thus more or less delivery time insensitive. Another characteristic is that the content of the packets must be transparently transferred (with low BER).

Background traffic – fundamental characteristics for QoS:

- the destination is not expecting the data within a certain time;
- preserve payload content.

A background application is one that does not carry delay information. In principle, the only requirement for applications in this category is that information should be delivered to the user essentially error free. However, it is emphasized that there is still a delay constraint, since data is effectively useless if it is received too late for any practical purpose.

3.4.1.3 Service category parameters

Service categories are characterized with parameters which are obtained either from market studies or from other sources. The following parameters are obtained from Report ITU-R M.2072:

- User density (users/km²)
- Session arrival rate per user (sessions/(s · user))
- Mean service bit rate (bit/s)
- Mean session duration (s/session)
- Mobility ratio.

The first four parameters characterize the demand of different service categories, while the mobility parameter is used in traffic distribution in § 3.6. Terminal mobility is closely related to application usage scenarios. Recommendation ITU-R M.1390 defines mobility as:

- in-building;
- pedestrian;
- vehicular.

The requirements depend upon the speed of the mobile stations. In market studies in Report ITU-R M.2072, the mobility classes are categorized as follows:

- Stationary (0 km/h)
- Low (> 0 km/h and < 4 km/h)
- High (> 4 km/h and < 100 km/h)
- Super-high (>100 km/h and < 250 km/h).

The range limits of the categories should be related to typical characteristics of cellular radio networks. For small cells the minimum time a user stay in a cell between handovers needs to be significantly longer than the handover initiation and execution time. Therefore for small cells the cell size limits the maximum supported velocity. For this reason, pico cells are typically limited to support up to pedestrian velocities (up to 3-10 km/h), micro cells up to urban vehicular speeds of 50 km/h and macro cells of mobile cellular radio networks cover the remaining range of user

velocity. For application of the mobility classes in the methodology, the mobility classes from market studies are re-interpreted as follows:

- Stationary/Pedestrian (0-4 km/h)
- Low (> 4 km/h and < 50 km/h)
- High (> 50 km/h).

The traffic of the “high” mobility class obtained from market studies is split into the “low” and “high” mobility classes for the methodology. The splitting needs to take into account the attributes of the considered service environments introduced in § 3.4.2 which can result in different splitting factors J_m in different service environments m . The mapping of traffic to the mobility classes is presented in Tables 3 and 4, where the J_m values are only examples:

TABLE 3
Mapping of mobility class

Mobility in market study	Mobility in methodology
Stationary	Stationary/pedestrian
Low	
High	Low (fraction J_m)
	High (fraction $1 - J_m$)
Super-high	

TABLE 4
Example J -values for mapping of mobility classes
in different service environments

Service environment m	J_m -value
1	1
2	1
3	1
4	1
5	0.5
6	0

In addition to the market related service category parameters which are calculated in § 3.5.2, the methodology requires parameters which are not obtainable from Report ITU-R M.2072. These parameters are listed in Table 5 and they are needed in capacity calculations in § 4.

TABLE 5

Service category parameters as inputs for spectrum calculation algorithm

Service category	SC1	SC2		–		SC20
Mean packet size (bit/packet)		–		–		
Second moment ⁽¹⁾ of packet size (bit/packet)		–		–		
Allowed mean packet delay (s)		–		–		
Allowed blocking rate (%)		–		–		

⁽¹⁾ The second moment of a random variable is a scalar value that is related to the variance of the random variable.

3.4.2 Service environment

Service environments represent common service usage and volume conditions.

Service environment (SE) is defined as a combination of service usage pattern and teledensity.

3.4.2.1 Service usage patterns

A service usage pattern is defined as a common user(s) behaviour in a given service area.

The service usage pattern is categorized according to an area where users exploit similar services and expect similar quality of service. The following service usage patterns are used in the methodology:

- Home
- Office
- Public area.

3.4.2.2 Teledensity

As defined in Recommendation ITU-R M.1390, population density and the number of devices per person are also important factors when considering service environments. The geographical area is therefore divided according to these factors into teledensity categories.

Each teledensity parameter is characterized by population density and communication device density. Teledensity is categorized into the following:

- Dense urban
- Suburban
- Rural.

3.4.2.3 Definition and attributes of service environments

Service environments are defined for the following combinations of teledensity and service usage patterns which are shown in Table 6.

In order to provide readers a more clear view of every service environments, Table 7 shows possible user group and exemplary application of each SE.

Spectrum requirements shall first be calculated separately for each teledensity. The final spectrum requirements is calculated by taking the maximum value among spectrum requirements for the three teledensity areas (dense urban, suburban and rural).