

REPORT ITU-R M.2078

Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced

(2006)

1 Introduction

To achieve the objectives related to the further development of IMT-2000 and IMT-Advanced, additional spectrum bandwidth beyond that identified for IMT-2000 at WARC-92 and WRC-2000 may be required.

Recommendation ITU-R M.1645 describes in particular the expectations concerning the future development of IMT-2000 and IMT-Advanced:

In the framework of technological advances and introduction of IMT-2000 mobile radiocommunications, agreement on uniform and co-ordinated strategies and approaches in the ITU has been and will continue to be a prerequisite for worldwide success.

A prominent strategic decision by the ITU with regard to the development and introduction of IMT-2000 was the recognition and application of the principle of identifying harmonised frequency bands on a global basis with the aid of footnotes in the Radio Regulations.

The Radiocommunication Assembly 2003 adopted Recommendation ITU-R M.1645 on the “Framework and overall objectives for the future development of IMT-2000 and systems beyond IMT-2000”. Special consideration was given to growing demand for wireless communications, which may result in higher data rates to meet user needs.

This Report provides results of technical studies on estimated spectrum requirements for the future development of IMT-2000 and for IMT-Advanced as defined by ITU-R, in accordance with Resolution 228 (Rev.WRC-03). The Report uses market data in the year 2010 onwards from external organisations outside ITU, which are addressed in Report ITU-R M.2072. The estimated spectrum requirements are calculated with the spectrum calculation methodology defined in Recommendation ITU-R M.1768. In the spectrum calculation for the future development of IMT-2000 and IMT-Advanced, new concepts were introduced, including a mix of services, multiple complementary systems, and Radio Access Techniques Groups (RATG). These were not used in the Recommendation ITU-R M.1390 for the additional spectrum calculation for IMT-2000.

The estimated total spectrum bandwidth requirement for both the RATG1 and RATG2 for the year 2020 is calculated in this Report to be 1 280 MHz (including spectrum already in use, or planned to be used, for RATG1). The calculations developed the estimated spectrum bandwidth requirements ranging from 1 280 MHz to 1 720 MHz (including spectrum already in use, or planned to be used, for RATG1) which represented a lower and higher market setting as developed from the data in Report ITU-R M.2072. It should be noted that this lower figure (1 280 MHz) is higher than the anticipated requirements for some countries which may have a need for less or no additional spectrum. In addition there are some countries where the requirement is larger than the higher value (1 720 MHz).

1.1 Service-related elements

User expectations are continually increasing with regard to the variety of services and applications. In particular, users will expect a dynamic, continuing stream of new applications, capabilities and services that are ubiquitous and available across a range of devices using a single subscription and a single identity (number or address). Versatile communication systems offering customized and ubiquitous services based on diverse individual needs will require flexibility in the technology in order to satisfy multiple demands simultaneously.

Multimedia traffic is increasing far more rapidly than speech, and will increasingly dominate traffic flows. There will be a corresponding change from predominantly circuit-switched to packet-based delivery. This change will provide the user with the ability to more efficiently receive multimedia services, including e-mail, file transfers, messaging and distribution services. These services can be either symmetrical or asymmetrical, and real-time or non real-time. They can consume high bandwidths, resulting in higher data rate requirements in the future.

Work has already begun on the convergence of telecommunication services such as digital broadcasting and commercial wireless services. The trend toward integration and convergence can be characterized by:

- connectivity (provision of a pipe, including intelligence in the network and the terminal);
- content (information, including push and pull services);
- commerce (transactions).

These trends may be viewed as the integration and convergence of information technology (IT), telecommunications, and content. This will result in new service delivery dynamics and a new paradigm in telecommunications where value added services, such as those which are location dependent, will provide enormous benefits to both the end users and the service providers.

Convergence of IT, media and telecommunications is just beginning in this digital world (e.g., HTML, XML, and IP). Also, TV on mobile is just starting and attracts customer interest even if, for the moment, streaming is not the adequate mode.

With the introduction of high-speed mobile data, the market is being redefined to give hope for a new trend of point-to-point relations (text, voice, image, video) and personal empowerment. 2004 can be considered as a turning point in the mobile world as “Year 1 of the Personal and Portable Internet”. “(Reference: [ITU Internet Reports 2004: The Portable Internet](#) and [ITU Internet Reports 2005: The Internet of Things.](#))”

Furthermore, “always on” communications will enable networked and interconnected devices providing relevant content and information whatever the location of the user. Although mobile data applications have brought Internet-like services to the pockets of many mobile phone users, future systems will not only include personal applications (e.g., cell phones), but also embedded services in inanimate objects that may be pervasive in nature.

1.2 Technology elements

Wireless communications comprises a wide range of technologies, services and applications that have come into existence to meet the particular needs of different market sectors and user environments. Different systems can be broadly characterized by:

- content and services offered;
- frequency bands of operation;
- standards defining the systems;
- data rates supported;

- bidirectional and unidirectional delivery mechanisms;
- degree of mobility;
- regulatory requirements; and
- cost.

Second generation systems were mainly designed for applications such as voice. IMT-2000 and IMT-Advanced will increasingly be designed as a combination of different radio access techniques to complement each other in an optimum way for different service requirements and radio environments. This will enable a common and flexible service platform for different services and applications.

Access to a service or an application may be performed using one system or may be performed using multiple systems simultaneously (e.g. a digital broadcast channel and a return channel using IMT-2000).

In the future operators may deploy a mix of technologies that could, at various stages in time and subject to market and regulatory considerations, incorporate cellular, wireless LAN, digital broadcast, satellite and other access systems. This will require the seamless interaction of these systems in order for the user to be able to receive a variety of content via a variety of delivery mechanisms depending upon the particular terminal capabilities, location and user profile.

Different radio access systems will be connected via flexible core networks. In this way, an individual user can be connected via a variety of different access systems to the networks and services he desires. The interworking between these different access systems in terms of horizontal and vertical handover and seamless service provision with service negotiation including mobility, security and QoS management will be a key requirement.

Such information is one key prerequisite for the estimation of frequency requirements for advanced wireless communications applications. However, most market studies undertaken to date tend to focus on the total communication market to be served by mobile and other advanced wireless services.

2 Scope

This Report:

- a) deals only with IMT-relevant future mobile communication RATG(s) focusing on spectrum requirements for the preparation of WRC-07 Agenda item 1.4, while Recommendation ITU-R M.1645 provides the framework of a wider range of future mobile communication RATG(s) in the year 2010 onwards;
- b) describes forecast traffic demands for future applications/services in overall mobile communication market in the year 2010 onwards, which may be supported by the capabilities of the future development of IMT-2000 and of IMT-Advanced;
- c) duly considers the results of service and market forecast stated in Report ITU-R M.2072 for the traffic demand estimation;
- d) determines the distribution ratio amongst RATGs in order to identify IMT-relevant traffic demands, taking into account the Report ITU-R M.2072;
- e) identifies the RATG features that will be suitable for the future development of IMT-2000 and IMT-Advanced in the context of WRC-07 Agenda item 1.4;
- f) refers to the methodology defined in Recommendation ITU-R M.1768;

- g) describes parameters, relating both to market/service and radio aspect, and their values, some of which are provided by Reports ITU-R M.2072 and ITU-R M.2074 respectively;
- h) provides the numerical results of the spectrum calculation together with input parameter values;
- i) determines the amount of spectrum needed to support applications/services provided by the pre-IMT, IMT-2000, future development of IMT-2000 and IMT-Advanced;
- j) this Report does not address the specific spectrum requirements relevant to the scenario of large coverage areas with low teledensity, and parameters relevant to this scenario are therefore not included.

3 Related ITU-R Recommendations and Reports

Recommendations:

ITU-R M.687	International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.819	International Mobile Telecommunications-2000 (IMT-2000) for developing countries
ITU-R M.1034	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.1457	Detailed specification of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.1645	Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000
ITU-R M.1768	Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000
ITU-T Q.1702	Long-term vision of network aspects for systems beyond IMT-2000

Reports:

ITU-R M.2072	World mobile telecommunication market forecast
ITU-R M.2074	Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000

4 Market trend of future mobile communication

Recommendation ITU-R M.1645 addresses the framework of future development of IMT-2000 and systems beyond IMT-2000.

Present mobile communication systems have evolved by continually adding additional system capabilities and enhancements, and the user will see a significant increase in capability through the future development of IMT-2000. IMT-Advanced will be realized by functional fusion of existing, enhanced and newly developed elements of IMT-2000, nomadic wireless access systems and other wireless systems with high commonality and seamless interworking.

Recommendation ITU-R M.1645 concluded that internationally agreed frequency bands will encourage in particular the adoption of IMT-Advanced systems. Common global spectrum should be the preferred objective to ensure global roaming and equipment-cost reduction through economies of scale.

To fulfil the above mentioned requirement, ITU-R developed and approved Question ITU-R 229/8 on the future development of IMT-2000 and IMT-Advanced. One element of the *decides* of this Question is the technical and operational characteristics needed to meet the requirements (such as utilization of identified frequency bands) for the ongoing enhancement of IMT-2000.

5 Radio access technique group (RATG) approach for spectrum estimation

5.1 RATG definition

Recommendation ITU-R M.1645 considers trends of users as well as of services and applications and identified three focussed capability areas:

- a) capability of IMT-2000,
- b) capability of new mobile access, and
- c) capability of nomadic/local area wireless access, as shown in Fig. 2 of the Recommendation.

The b) and c) capability areas were recognised as new capabilities to be provided by IMT-Advanced systems.

The Recommendation also addresses a mix of services and multiple delivery mechanisms which convey the traffic of the services. Among these delivery mechanisms, some systems like IMT-2000 have detailed specification of their radio interfaces, while some new systems do not yet have detailed specifications for the radio interface(s).

It was decided that the spectrum calculation methodology for the future development of IMT-2000 and IMT-Advanced should have flexibility to handle both emerging technologies and well-characterized systems. Recommendation ITU-R M.1768 sets the guideline that the methodology should be *technology neutral and generic*. Accordingly, the concept of radio access technique groups (RATG) was introduced in Report ITU-R M.2074 in order to address both types of systems: one that does not yet have detailed specifications and others that have detailed specifications. Therefore, RATG can be defined as follows;

Radio access technique group (RATG): *a reference system model* that can best accommodate a particular area of capabilities identified in Fig. 2 of Recommendation ITU-R M.1645.

In other words, a RATG can be a generic reference model with minimum system specifications required to determine spectrum requirements. The RATG will be defined in more detail to be a Global Core Specification (GCS) at a later stage of standardization.

Spectrum requirement estimations need to take into account the relevant technologies. The basis for the grouping is the Agenda item 1.4, Resolution 228 (Rev.WRC-03) and Recommendation ITU-R M.1645.

The RAT Groups are the following:

- *Group 1:* Pre-IMT systems, IMT-2000 and its enhancements.
 - This group covers the cellular mobile systems, IMT-2000 systems and their enhancements.
- *Group 2:* IMT-Advanced as described in Fig. 2 of Recommendation ITU-R M.1645 (e.g., new mobile access and new nomadic/local area wireless access), but not including systems already described in any other RAT groups.
- *Group 3:* Existing radio LANs and their enhancements.
- *Group 4:* Digital mobile broadcasting systems and their enhancements.

- This group covers systems aimed at broadcasting to mobile and handheld terminals.

The justifications for each group are the following:

Group 1: The need for this RAT Group stems directly from the Agenda item 1.4 and Recommendation ITU-R M.1645. The proposal to include IMT-2000 and its future enhancements into a single RAT Group is in line with the M.1645 expectation that “there will be a steady and continuous evolution of IMT-2000 to support new applications, products and services”, which is also confirmed by ongoing standardization activities.

Pre-IMT systems are included in RAT Group 1 for the following reasons:

- Pre-IMT systems cover a subset of the IMT-2000 services and therefore the corresponding traffic can be aggregated with IMT-2000 traffic.
- Most bands for pre-IMT-2000 technologies are identified for IMT-2000, and as such those bands will be taken into account in the estimations.
- Presence of pre-IMT systems can technically be taken into account by appropriate adjustments in radio parameters of RAT Group 1, e.g. the spectral efficiency, so that the value of each radio parameter is *representative* for all RATs in the group.
- The time span for the market data is beyond 2015, when significance of the pre-IMT systems may be decreasing in some countries or Regions. However, there will be differences in different countries and Regions with respect to the licensing, market development, migration to IMT-2000, etc. Covering such questions is not in the scope of WRC-07 Agenda item 1.4.

Group 2: The need for this RAT Group stems directly from Agenda item 1.4 and Recommendation ITU-R M.1645. IMT-Advanced will cover new mobile access and new nomadic/local area access capabilities. The motivation for a separate RAT group compared to Group 1 is that IMT-Advanced systems are expected to have significantly differing RAT characteristics and capabilities than IMT-2000 and its future developments.

Group 3: The need for taking this RAT Group into account comes from Recommendation ITU-R M.1645. IMT-2000 and IMT-Advanced are identified to have a relationship with RLAN's. It can be expected that existing RLAN's will share a portion of the relevant total traffic. WRC-03 identified globally common spectrum for RLAN's, which allows considerable capacity for such networks.

Group 4: The need for taking this RAT Group into account comes also from Recommendation ITU-R M.1645 as well as from the fact that new mobile broadcasting services based on technologies such as IP datacast are expected to emerge in the coming years. These services will provide point-to-multipoint services that cover part of the total mobile market.

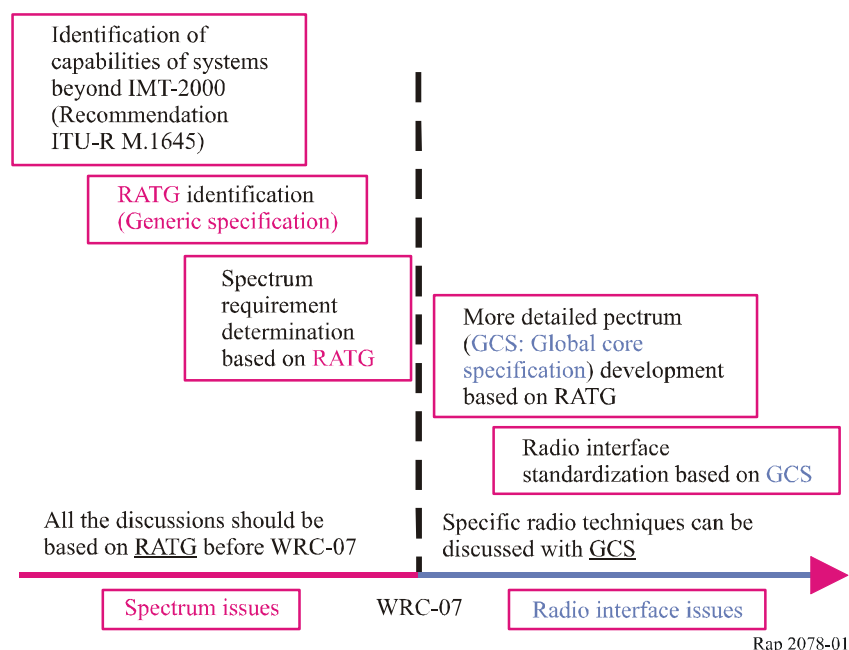
5.2 RATG approach to determine spectrum requirements

With the introduction of the RATG concept, spectrum requirement issues and radio interface issues, in regards to timeframes can be separately discussed. It is generally known that the amount of spectrum needed for a particular system is based on some system parameters but not all the system parameters which characterise the system. Since a RATG has some system parameters which are technology-neutral but indispensable for spectrum requirements determination, it is possible to consider spectrum requirements for RATG(s) without determining the full set of system parameters (including technology-dependent parameters). This is very beneficial and practical for spectrum requirement considerations, because it may take some time for the identified spectrum to be available and spectrum identification should be performed well in advance of the system deployment.

On the contrary, from the radio interface perspective, it is better to employ the latest technology when developing radio interface standards because the latest techniques would contribute to the improvement of spectrum efficiency. The conflict of the early spectrum identification and the latest technology adoption can be solved by introducing the concept of RATGs, i.e. we can discuss spectrum requirements by using generic and technologically-neutral RATG at first, then we can make the RATG detailed specifications later as a GCS and discuss radio interface techniques with the GCS, as shown in Fig. 1.

Therefore, it was decided to determine spectrum requirements based on RATGs but not specific systems before WRC-07.

FIGURE 1
Two step approach for the future development of IMT-2000 and for IMT-Advanced



6 Time shift approach to global common market

In this Report the spectrum requirements are calculated for RAT Group 1 and RAT Group 2 in three different forecast years, i.e. 2010, 2015 and 2020. The spectrum requirements are calculated with the methodology presented in Recommendation ITU-R M.1768 using the set of input parameter values which is given in § 7.

The spectrum calculation is based on “global common market” presented in Report ITU-R M.2072 which characterises the future mobile market in 2010, 2015 and 2020. Report ITU-R M.2072 defines ranges for the market parameters while the spectrum calculations require unique values for the different input parameters.

There are regional differences in the market development, i.e. in some parts of the world a particular level of market development may be reached earlier or later than in the (average) “global common market”. To characterize the difference in the market development and RAT Group deployment scenarios in different countries, the time shift approach is used to calculate the spectrum requirements. With this approach, unique sets of market parameter values are derived from Report ITU-R M.2072 for 2010, 2015 and 2020. Due to the regional differences in the market

development, the parameter sets are interpreted to be valid in different countries at different time intervals.

Using the unique market prediction sets for 2010, 2015 and 2020, the spectrum requirements can be calculated to a default scenario, called “middle” scenario. From these three Market predictions/spectrum requirements two different additional scenarios, i.e. “earlier” and “later”, are derived. These two additional scenarios show the time shift market utilisation in different densely populated countries. These additional scenarios “earlier” and “later”, together with “middle” scenario characterise the different speed of system deployment and market development in different areas.

This approach and all the scenarios predict that in different time scale the predicted market will saturate to similar situation in different densely populated countries. The early identification of IMT-Advanced spectrum to support the “saturated” mobile market brings additional benefits. Even if the identification would take place in WRC-07, the time scale of the usage of available spectrum might differ between different administrations e.g. according different chosen time scenarios.

Figure 2 shows the time shift approach on conceptual level. Some countries, wishing to implement future mobile systems as early as possible, would have a view of the system deployment as depicted in blue (top) line. This kind of deployment and market setting would refer to “earlier” market scenario. Some other countries would have deployment and market setting referred “middle” scenario shown in light blue (middle) line. This would be the default setting for spectrum requirement calculations. Those countries whose market development and/or system deployment is assumed to develop slower would have view shown in magenta (bottom) line, this is referred as “later” scenario. The allocation of identified spectrum might differ from market prediction. This difference is assumed to be mostly apparent between year index 2010 and 2015. Thus the trends of spectrum requirements between “2010” and “2020” are marked with dashed line.

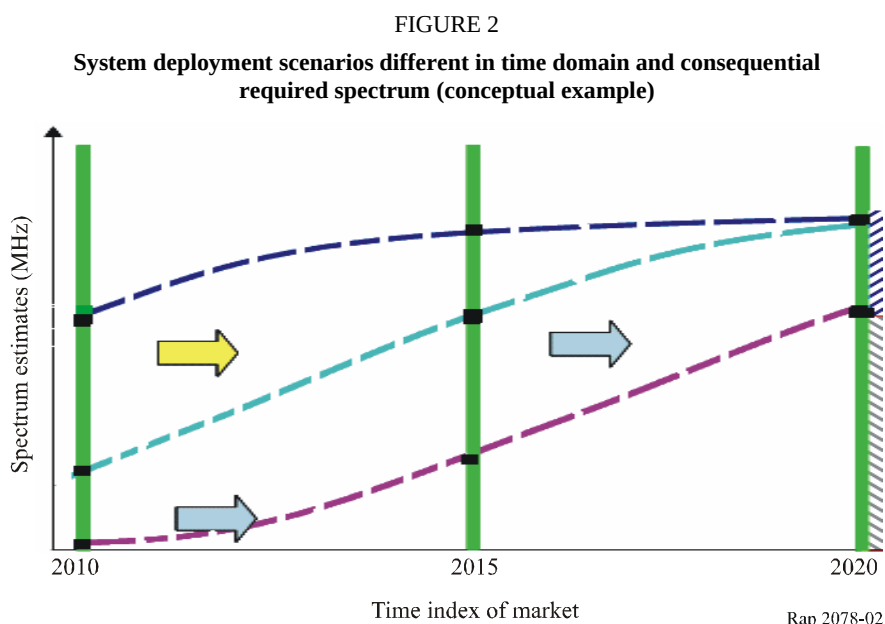


Figure 2 shows how the three example scenarios in three country groups have different shifted time scenarios starting in different time point, e.g. difference by 5 years. All three groups have same system deployment scenario assumption, regardless of starting time, which can be seen in the shape of the curves.

7 Elements to be used for spectrum calculation

7.1 Service elements of the estimate

7.1.1 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

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	SC 1	SC 6	SC 11	SC 16
High multimedia	SC 2	SC 7	SC 12	SC 17
Medium multimedia	SC 3	SC 8	SC 13	SC 18
Low rate data and low multimedia	SC 4	SC 9	SC 14	SC 19
Very low rate data ⁽¹⁾	SC 5	SC 10	SC 15	SC 20

⁽¹⁾ This includes speech and SMS.

7.1.2 Service environments

Service environments are defined for the following combinations of teledensity and service usage patterns as shown in Table 2.

TABLE 2
The identification of service environments

Teledensity Service usage pattern	Dense urban	Sub-urban	Rural
Home	SE 1	SE 4	SE6
Office	SE 2	SE 5	
Public area	SE 3		

7.1.3 Service category parameters

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

- 1 User density (users/km²).
- 2 Session arrival rate per user (sessions/(s*user)).
- 3 Mean service bit rate (bit/s).
- 4 Mean session duration (s/session).
- 5 Mobility ratio.

The first four parameters characterise the demand of different service categories, while the mobility parameter is used in traffic distribution. Terminal mobility is closely related to application usage scenarios. In market studies in Report ITU-R M.2072, the mobility classes are categorized as follows:

- 1) Stationary (0 km/h)
- 2) Low (> 0 km/h and < 4 km/h)
- 3) High (> 4 km/h and < 100 km/h)
- 4) 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 application of the mobility classes in the methodology, the mobility classes from market studies are re-interpreted as follows:

- 1) Stationary/pedestrian (0 – 4 km/h)
- 2) Low (> 4 km/h and < 50 km/h)
- 3) 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 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.

TABLE 3
Mapping of mobility class

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

TABLE 4
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

The values for the service category parameters that are obtained from market studies are presented in § 7.2. In addition to the market related service category parameters, the methodology's capacity calculation algorithms require parameters which are not obtainable from Report ITU-R M.2072. Different parameters are needed for circuit switched and packet switched service categories. For service categories treated as circuit switched the required parameter values are listed in Table 5.

The quality of service used in the tele-traffic models can have a noticeable impact on the spectrum requirement. The current values chosen must reflect the performance to be expected.

TABLE 5
**Service category parameters: Common for traffic class of
circuit-switched traffic for years 2010, 2015 and 2020**

Parameter	Traffic class	
	Conversational	Streaming
	SC1 – SC5	SC6 – SC10
Blocking probability	0.01	0.01

For packet switching the required parameter values are given in Tables 6 to 8, Tables 9 to 11 and Tables 12 to 14 for 2010, 2015 and 2020, respectively. Values are only specified for the service categories that will be subject to the packet-switched capacity calculation as defined by Recommendation ITU-R M.1768, i.e., for service categories 11-20.

TABLE 6
Mean IP packet size per service category for the year 2010 (unit: byte)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	1114.00	853.83
High multimedia	Treated as circuit-switched	Treated as circuit-switched	1 345.78	1 111.54
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	790.59	1 114.00
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	92.86	207.00
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	44.76	207.00

TABLE 7

Second moment of the IP packet size per service category for the year 2010 (unit: byte²)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	1 549 475.00	1 132 635.50
High multimedia	Treated as circuit-switched	Treated as circuit-switched	1 988 453.75	1 545 450.23
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	1 019 787.76	1 549 475.00
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	17 884.41	182 513.50
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	6 381.06	182 513.50

TABLE 8

Mean delay requirements per service category for the year 2010 (unit: s)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	0.2971	0.0648
High multimedia	Treated as circuit-switched	Treated as circuit-switched	0.0867	0.2131
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	0.9333	8.9120
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	2.7813	4.9444
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	0.4224	44.5000

TABLE 9

Mean IP packet size per service category for the year 2015 (unit: byte)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	3 271.62	3 054.00
High multimedia	Treated as circuit-switched	Treated as circuit-switched	772.75	3 372.92
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	1 787.18	3424.00
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	103.86	235.50
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	45.74	235.50

TABLE 10

Second moment of the IP packet size per service category for the year 2015 (unit: byte²)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	27 378 193.49	20 332 660.50
High multimedia	Treated as circuit-switched	Treated as circuit-switched	5 942 936.47	28 236 339.72
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	14 849 326.83	28 667 000.00
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	154 415.82	1 827 768.50
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	20 157.67	1 827 768.50

TABLE 11

Mean delay requirements per service category for the year 2015 (unit: s)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	0.1490	0.0648
High multimedia	Treated as circuit-switched	Treated as circuit-switched	0.1019	0.4968
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	0.7461	13.6960
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	4.9444	4.9444
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	0.4224	44.5000

TABLE 12

Mean IP packet size per service category for the year 2020 (unit: byte)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	3 292.23	3 054.00
High multimedia	Treated as circuit-switched	Treated as circuit-switched	1 847.82	3 307.86
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	1 021.60	1 369.33
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	102.56	235.50
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	47.61	235.50

TABLE 13

Second moment of the IP packet size per service category for the year 2020 (unit: byte²)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	27 552 481.16	20 332 660.50
High multimedia	Treated as circuit-switched	Treated as circuit-switched	15 349 865.20	27 691 445.33
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	6 592 429.07	11 523 733.33
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	138 595.74	1 827 768.50
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	36 019.39	1 827 768.50

TABLE 14

Mean delay requirements per service category for the year 2020 (unit: s)

Traffic class Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as circuit-switched	Treated as circuit-switched	0.1490	0.0648
High multimedia	Treated as circuit-switched	Treated as circuit-switched	0.1019	0.4968
Medium multimedia	Treated as circuit-switched	Treated as circuit-switched	1.5280	2.9670
Low rate data and low multimedia	Treated as circuit-switched	Treated as circuit-switched	2.7813	4.9444
Very low rate data	Treated as circuit-switched	Treated as circuit-switched	0.4224	44.5000

7.1.4 Radio environment parameters

Tables 15a) and 15b) show the cell/sector area per radio environment, without and with penetration loss respectively. The penetration losses of 18, 15, 12 dB are used for dense urban, sub-urban and rural in the calculation. Table 16 shows the population coverage percentage of the radio environments in each service environment. The population coverage percentage values are given separately for the three different forecast years.

TABLE 15
Assumed cell area per radio environment (km²)

a) Without penetration loss

Radio environment	Teledensity		
	Dense urban	Sub-urban	Rural
Macro cell	0.65	0.65	0.65
Micro cell	0.10	0.10	0.10
Pico cell	0.0016	0.0016	0.0016
Hot spot	0.00065	0.00065	0.00065

b) With penetration loss

Radio environment	Teledensity		
	Dense urban	Sub-urban	Rural
Macro cell	0.10	0.15	0.22
Micro cell	0.07	0.10	0.15
Pico cell	0.0016	0.0016	0.0016
Hot spot	0.00065	0.00065	0.00065

TABLE 16
Population coverage percentage (%) of the radio environments
in each service environment in 2010, 2015 and 2020, respectively

Service environment	Radio environments 2010			
	Macro cell	Micro cell	Pico cell	Hot spot
1	100	90	0	80
2	100	90	20	80
3	100	95	20	10
4	100	15	0	80
5	100	40	35	20
6	100	0	10	50
Service environment	Radio environments 2015			
	Macro cell	Micro cell	Pico cell	Hot spot
1	100	90	10	80
2	100	90	20	80
3	100	95	30	25
4	100	35	0	80
5	100	50	35	20
6	100	0	10	50

TABLE 16 (end)

Service environment	Radio environments 2020			
	Macro cell	Micro cell	Pico cell	Hot spot
1	100	90	20	80
2	100	90	20	80
3	100	95	40	40
4	100	35	0	80
5	100	50	35	20
6	100	0	10	50

The radio environments are characterised by the relation between Service environments and radio deployment schemes e.g. micro cellular deployment is considered unfeasible in rural service environment, because no below roof-top-deployment can be accomplished.

7.2 Market overview and forecasted overall traffic

It is recognised that different countries will have different market environments.

These are due to differences in the demographics and differences in the maturity of the markets of the different countries. The differences of demographics of different countries are taken into account by considering the user density values. The differences in the maturity of the markets are taken into account by considering a time shift approach.

The specific values of the parameters below are determined for each service category (SC) and for each service environment (SE) based on Report ITU-R M.2072.

- Number of subscribers (Market scale) (users/km²)
- Number of session attempts per user per time (1/user/s)
- Mean service bit rate (bit/s)
- Average session duration (s)
- Mobility ratio (stationary/low/high/super-high)

These parameters are obtained from the responses to the questionnaire on services and markets from 27 organizations, which can be referenced in Annex 2 of Report ITU-R M.2072. Report ITU-R M.2072 suggests ranges of parameters for each of the following years 2010, 2015, and 2020. The detailed information on these parameters including the ranged values for these parameters can be referenced in § 8 “Market related parameters for spectrum calculation” and Annex 4 of Report ITU-R M.2072. Further information, such as the method to obtain these values, can also be referenced in Report ITU-R M.2072¹.

¹ The averaging process used in the Report ITU-R M.2072 to derive the traffic characteristics for each service category can result in an under-estimation of the spectrum requirement if any of the contributory services have a significantly higher service rate than the average. This will only be important for circuit switched traffic in the highest service category.

The unique values for the market parameters selected from the ranges given in Report ITU-R M.2072 are determined with percentage values (0-100) for parameters a) to d). Percentage value 0 means the minimum value inside the range defined by Report ITU-R M.2072 and 100 means the maximum value inside the range defined by Report ITU-R M.2072. For the mobility ratios three scenarios are considered: lowest (1), medium (2) and highest mobility scenario (3).

Separate tables are given to represent lower user densities and higher user densities. The values for the market settings were chosen to follow a basic approach of using the same percentage value in all service categories for parameters Q: session arrival rate per user, R: mean service bit rate, μ : average session duration, in order to preserve the proportions and between service categories and trends over time foreseen by the Report ITU-R M.2072.

The percentages for the market parameters and the selected mobility scenarios are shown in Tables 17a and 17b. Note that SCs that do not have a range in Report ITU-R M.2072 are not affected by using different market setting values. These are marked with the note “(No range M.2072)” in the tables below. The exact values for the market parameters in Table 17 are shown in Annex 1.

TABLE 17a

Market attributes in year 2010, 2015, 2020 for lower user densities

SC	U (%)	Q (%)	R (%)	M (%)	Mobility ratio
1	5	30	30	30	2 (No range M.2072)
2	5	30	30	30	2
3	5	30	30	30	2
4	5	30	30	30	2
5	5	30	30	30	2
6	5	30	30	30	2 (No range M.2072)
7	5	30	30	30	2
8	5	30	30	30	2
9	5	30	30	30	2 (No range M.2072)
10	5	30	30	30	2
11	5	30	30	30	1
12	5	30	30	30	2
13	5	30	30	30	2
14	5	30	30	30	2
15	5	30	30	30	2
16	5	30	30	30	2 (No range M.2072)
17	5	30	30	30	2
18	5	30	30	30	2 (No range M.2072)
19	5	30	30	30	2 (No range M.2072)
20	5	30	30	30	2

TABLE 17b

Market attributes in year 2010, 2015, 2020 for higher user densities

SC	U (%)	Q (%)	R (%)	μ (%)	Mobility ratio
1	25	30	30	30	2 (No range M.2072)
2	25	30	30	30	2
3	25	30	30	30	2
4	25	30	30	30	2
5	25	30	30	30	2
6	25	30	30	30	2 (No range M.2072)
7	25	30	30	30	2
8	25	30	30	30	2
9	25	30	30	30	2 (No range M.2072)
10	25	30	30	30	2
11	25	30	30	30	1
12	25	30	30	30	2
13	25	30	30	30	2
14	25	30	30	30	2
15	25	30	30	30	2
16	25	30	30	30	2 (No range M.2072)
17	25	30	30	30	2
18	25	30	30	30	2 (No range M.2072)
19	25	30	30	30	2 (No range M.2072)
20	25	30	30	30	2

7.3 RATG specification required for spectrum estimation**7.3.1 Radio parameters for spectrum calculation methodology**

Tables 18 to 21 introduce input parameters of RAT Groups 1, 2, 3 and 4, respectively.

TABLE 18

Radio parameters for RATG 1

Parameters	Macro cell	Micro cell	Pico cell	Hot spot
Application data rate (Mbit/s)	20	40	40	—
Supported mobility classes	Stationary/ pedestrian, low, high	Stationary/ pedestrian, low	Stationary/ pedestrian	—
Guard band between operators (MHz)	0			—
Minimum deployment per operator per radio environment (MHz)	40	40	40	—
Support for multicast	Yes			—
Number of overlapping network deployment	1			

TABLE 19
Radio parameters for RATG 2

Parameters	Macro cell	Micro cell	Pico cell	Hot spot
Application data rate (Mbit/s)	50	100	1 000	1 000
Supported mobility classes	Stationary/ pedestrian, low, high	Stationary/ pedestrian, low	Stationary/ pedestrian	Stationary/ pedestrian
Guard band between operators (MHz)	0			
Support for multicast	Yes			
Minimum deployment per operator per radio environment (MHz)	20	20	120	120
Number of overlapping network deployment	1			

TABLE 20
Radio parameters for RATG 3

Parameters	Macro cell	Micro cell	Pico cell	Hot spot
Application data rate (Mbit/s)	–	–	50	100
Supported mobility classes	–	–	Stationary/ pedestrian	Stationary/ pedestrian
Support for multicast (yes=1, no=0)	Yes			

NOTE 1 – The above values were taken out of the Report ITU-R M.2074.

TABLE 21
Radio parameters for RATG 4

Parameters	Macro cell
Application data rate (Mbit/s)	2
Supported mobility classes	Stationary/pedestrian, low, high

7.3.2 Spectrum efficiency matrix

The area spectral efficiency is used in the spectrum requirement calculations to convert the capacity requirements in terms of bit/s/cell to the spectrum requirements in Hz. The area spectral efficiency factors should be measured below the IP layer and/or above L2. The spectral efficiency includes all RAT specific overheads, retransmissions load, scheduling, etc. Even though for several teledensities the spectral efficiency might be the same, it is possible that the spectral efficiency will also vary between teledensities.

The spectral efficiency values for RAT Group 1 are shown in Table 22. They are based on figures that have been proposed for the long term evolution of IMT-2000 technologies. The spectral efficiency values for RAT Group 2 are assumed to be dependent on the forecast year. The values for RAT Group 2 in 2010, 2015 and 2020 are shown in Tables 23a to 23e, respectively.

TABLE 22a

Area spectral efficiency RAT Group 1 2010 (bit/s/Hz)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	1	2	2	–
Suburban	1	2	2	–
Rural	1	2	2	–

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	0.5	1	1	–
Suburban	0.5	1	1	–
Rural	0.5	1	1	–

TABLE 22b

Area spectral efficiency RAT Group 1 2015 (bit/s/Hz)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	1.5	3	3	–
Suburban	1.5	3	3	–
Rural	1.5	3	3	–

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	0.75	1.5	1.5	–
Suburban	0.75	1.5	1.5	–
Rural	0.75	1.5	1.5	–

TABLE 22c

Area spectral efficiency RAT Group 1 2020 (bit/s/Hz)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	2	4	4	–
Suburban	2	4	4	–
Rural	2	4	4	–

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	1	2	2	–
Suburban	1	2	2	–
Rural	1	2	2	–

Table 23a is based on simulation results of wireless technologies known in 2006 and expected to be implemented in 2010. Table 23e is derived from theoretical limits (Shannon's Theorem) allowing an estimated margin for implementation. Tables 23b to 23 d represent possible evolution paths within the values shown in Tables 23a and 23e.

TABLE 23a

Area spectral efficiency RAT Group 2 in year 2010**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	2	2.5	3	5
Suburban	2	2.5	3	5
Rural	2	2.5	3	5

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	1	1.2	1.5	2.5
Suburban	1	1.2	1.5	2.5
Rural	1	1.2	1.5	2.5

TABLE 23b

Area spectral efficiency RATG 2 in year 2015 (Set 1)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	4.25	5.5	7	8.25
Suburban	4.25	5.5	7	8.25
Rural	4.25	5.5	7	8.25

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	2.125	2.75	3.5	4.125
Suburban	2.125	2.75	3.5	4.125
Rural	2.125	2.75	3.5	4.125

TABLE 23c

Area spectral efficiency RATG 2 in year 2015 (Set 2)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	4	5.25	6.5	7.5
Suburban	4	5.25	6.5	7.5
Rural	4	5.25	6.5	7.5

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	2.0	2.625	3.25	3.75
Suburban	2.0	2.625	3.25	3.75
Rural	2.0	2.625	3.25	3.75

TABLE 23d

Area spectral efficiency RATG 2 in year 2020 (Set 1)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	4.5	6	7.5	9
Suburban	4.5	6	7.5	9
Rural	4.5	6	7.5	9

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	2.25	3	3.75	4.5
Suburban	2.25	3	3.75	4.5
Rural	2.25	3	3.75	4.5

TABLE 23e

Area spectral efficiency RATG 2 in year 2020 (Set 2)**Unicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	6	8	10	10
Suburban	6	8	10	10
Rural	6	8	10	10

**Multicast area spectral efficiency
(bit/s/Hz/cell)**

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	3	4	5	5
Suburban	3	4	5	5
Rural	3	4	5	5

7.4 Distribution ratios among available RAT groups

The RAT groups distribution ratio depends on the available RATs in each radio environment and service environment. Of the total traffic that goes to a particular radio environment, the distribution to the RAT groups is as defined in Recommendation ITU-R M.1768. This contains the distribution ratios among available RAT groups. The distribution ratios are given separately for each of the 3 years 2010, 2015 and 2020, because with progressing market introduction of RATG members a shift in traffic distribution towards more modern RATGs can be expected. The values are shown in Tables 24a to 24c for 2010, 2015 and 2020.

TABLE 24a

Distribution ratios among available RAT groups in 2010

Available RAT groups	Distribution ratio (%)		
	RATG 1	RATG 2	RATG 3
1	100	–	–
2		100	
3	–	–	100
1, 2	100	0	-
1, 3	30	–	70
2, 3	–	0	100
1, 2, 3	30	0	70

TABLE 24b

Distribution ratios among available RAT groups in 2015

Available RAT groups	Distribution ratio (%)		
	RATG 1	RATG 2	RATG 3
1	100	–	–
2		100	
3	–	–	100
1, 2	50	50	-
1, 3	20	–	80
2, 3	–	30	70
1, 2, 3	20	20	60

TABLE 24c

Distribution ratios among available RAT groups in 2020

Available RAT groups	Distribution ratio (%)		
	RATG 1	RATG 2	RATG 3
1	100	–	–
2		100	
3	–	–	100
1, 2	10	90	-
1, 3	10	–	90
2, 3	–	50	50
1, 2, 3	10	45	45

8 Spectrum requirements of the IMT-related RAT Groups

The spectrum requirements are calculated for RAT Group 1 (i.e. pre-IMT, IMT-2000, and its enhancements) and RAT Group 2 (i.e. IMT-Advanced) in 2010, 2015 and 2020. The spectrum requirements are calculated with the time shift approach described in § 6 using the input parameter values given in § 7. The input parameter values from § 7 are used to calculate the spectrum requirements for default “middle” scenario. The results for “later” and “earlier” scenario are derived by shifting the results from the “middle scenario”.

Table 25 shows the spectrum requirements for the average level of market development. There are expected to be regional differences in the market development, i.e. and some parts of the world a particular level of market development may be reached earlier or later than in the (average) “global common market”. This is described as the “time shift approach” (see § 6).

TABLE 25

Predicted spectrum requirements for both RATG 1 and RATG 2 (MHz)

Market setting	Spectrum requirement for RATG 1			Spectrum requirement for RATG 2			Total spectrum requirement		
	y2010	y2015	y2020	y2010	y2015	y2020	y2010	y2015	y2020
Higher market metting	840	880	880	0	420	840	840	1 300	1 720
Lower market setting	760	800	800	0	500	480	760	1 300	1 280

Tables 26a) and b) represent the middle scenario of the time shift approach.

TABLE 26

Ranges of predicted spectrum requirements (MHz)

a) Lower user density market development

	1 network (see Note 3)	2 networks (see Note 1)	3 networks (see Note 1)	4 networks (see Note 1)	5 networks (see Note 1)
RATG 1 (see Note 2)	800	880	840	1 120	1 000
RATG 2	480	560	720	800	1 000
RATG 1 + RATG 2	1 280	1 440	1 560	1 920	2 000

TABLE 26 (*end*)

b) Higher user density market development

	1 network (see Note 3)	2 networks (see Note 1)	3 networks (see Note 1)	4 networks (see Note 1)	5 networks (see Note 1)
RATG 1 (see Note 2)	880	880	960	1 120	1 200
RATG 2	840	880	1 020	1 120	1 300
RATG 1 + RATG 2	1 720	1 760	1 980	2 240	2 500

NOTE 1 – When more than one network is present in a country the total spectrum requirement may be higher in order to account for packaging the spectrum (integer multiples of 40 MHz for RATG1).

NOTE 2 – The spectrum estimate for RATG1 for the year 2010 may seem high when considering current network deployments. However, the total estimation was performed using a process established by Recommendation ITU-R M.1768 and technical characteristics predicted for RATG1 in the evolution of IMT-2000 technologies. Furthermore there is not enough statistical market data to predict the exact requirements for RATG1.

NOTE 3 – It should be noted that in Recommendation ITU-R M.1768 and Report ITU-R M.2074 the associated terminology relating to the term ‘Network’ is the term ‘number of overlapping network deployments’.

9 Conclusions

This report presents the results of the calculation of spectrum requirements for RAT Group 1 (i.e. pre-IMT, IMT-2000, and its enhancements) and RAT Group 2 (i.e. IMT-Advanced) in 2010, 2015 and 2020.

This report uses the spectrum calculation methodology presented in the Recommendation ITU-R M.1768 and defines values for all the input parameters needed for spectrum calculations. The spectrum requirements have been calculated for two RAT Groups in the years 2010, 2015 and 2020.

The predicted total spectrum bandwidth requirement for both the RATG 1 and RATG 2 for the year 2020 is calculated in this Report to be 1 280 MHz (including spectrum already in use, or planned to be used, for RATG 1²). The calculations developed the spectrum bandwidth requirements ranging from 1 280 MHz to 1 720 MHz (including spectrum already in use, or planned to be used, for RATG 1²) which represented a lower and higher market setting as developed from the data in Report ITU-R M.2072. It should be noted that this lower figure (1 280 MHz) is higher than the requirements for some countries. In addition there are some countries where the requirement is larger than the higher value (1 720 MHz).

The deployment scenarios reflect the differences in the quantitative market development and RAT deployment status in different parts of the world.

The results show that additional spectrum is needed, beyond that identified for IMT-2000 at WARC-92 and WRC-2000.

² RATGroup 1: Pre-IMT systems, IMT-2000 and its enhancements.

- This group covers the cellular mobile systems, IMT-2000 systems and their enhancements in accordance with Footnotes 5.317A, 5.384A and 5.388 to the table of frequency allocations.