

REPORT ITU-R M.2074

**Radio aspects for the terrestrial component
of IMT-2000 and systems beyond IMT-2000**

(2005)

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1 Scope

This Report provides radio-related technical information which is relevant to the preparations of WRC-07 Agenda item 1.4. It describes technical matters related to radio aspects such as requirement for technical characteristics that are needed for the spectrum requirements calculations, values of the required radio parameters, spectrum efficiency values, and suitable spectrum range preference from a technical aspect. These matters are reflected in the process to calculate the required spectrum and to determine suitable frequency ranges for the future development of IMT-2000 and systems beyond IMT-2000 from the year 2010 onwards to fulfil the framework shown in Recommendation ITU-R M.1645.

2 Introduction

Recommendation ITU-R M.1645 defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000. That framework is based on the global user and technology trends, including the needs of developing countries. Further ITU-R Recommendations will develop these concepts in more detail. This Report addresses technical matters related to radio aspects for the future development of IMT-2000 and systems beyond IMT-2000.

WRC-03 set an agenda item for WRC-07 to consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 and invited ITU-R to report, in time for WRC-07, on the results of studies on the spectrum requirements and potential frequency ranges suitable for the future development of IMT-2000 and systems beyond IMT-2000.

Market trends in future systems such as the amount of traffic in the year 2010 onwards and predictions of the future technical characteristics, such as radio parameters, will be considered as important inputs for the calculation of required spectrum bandwidth and the determination of suitable frequency ranges for the future development of IMT-2000 and systems beyond IMT-2000. Market trends are detailed in Report ITU-R M.2072.

Studies in radio aspects are indispensable for the calculation of required spectrum bandwidth and the determination of suitable frequency ranges, taking into account technical trends in the year 2010 onwards. These studies should be technology neutral and include relevant technical factors such as radio environments, radio parameters, and spectrum efficiency.

3 The framework on IMT-2000, future developments of IMT-2000, and systems beyond IMT-2000

The high level framework of the future development of IMT-2000 and systems beyond IMT-2000 includes:

- future development of IMT-2000, new capabilities of systems beyond IMT-2000;
- relationship of IMT-2000, systems beyond IMT-2000, and other access systems, as described in Recommendation ITU-R M.1645.

The new capabilities are comprised of new mobile access capabilities and new nomadic/local area wireless access capabilities.

3.1 IMT-2000 and its enhancements

IMT-2000 and its enhancements are expected to continue supporting wide area mobility capability and will further address user needs for low and medium data rate services with increased spectrum efficiency. These include all kinds of speech services, SMS, low and medium multimedia and location-based services. Along with that, the initial enhancements of IMT-2000, for which

standards are already being developed, will be followed by further enhancements that could increase the peak aggregate useful data rate up to approximately 30 Mbit/s under favourable circumstances. IMT-2000 and its enhancements should support low to high mobility since these systems would be mainly deployed in a cellular environment. In such an environment, both line-of-sight (LoS) and non line-of-sight (NLoS) should be considered.

3.2 New mobile access

A new mobile access is envisaged to handle low to high mobility applications with a wide range of supported data rates according to economic and service demands in multi-user environments with target peak data rates of up to approximately 100 Mbit/s with very high spectrum efficiency. It is expected that this new mobile access provides high bitrate applications, such as MMS, video streaming and super high multimedia, as well as various kinds of simultaneous medium even if their data rates do not require high speed. Since a new mobile access would be deployed in cellular and hotspot environments, low to high mobility should be supported. Both LoS and NLoS should be considered in new mobile access.

3.3 New nomadic/local area wireless access

A new nomadic/local area wireless access is predicted to handle low mobility applications with a wide range of data rates according to economic and service demands. Since it is expected that users would download or upload large-size data with high speed in a particular space, a new nomadic/local area wireless access should support peak data rates up to 1 Gbit/s in low mobility. It is anticipated that the new nomadic/local area wireless access would be deployed according to economic and service demands in isolated environments referred to as hot spots.

4 Radio access techniques (RATs) and RAT groups

4.1 Justification for RAT group approach for the spectrum requirements calculation methodology

WRC-07 agenda item 1.4 states: “to consider frequency related matters for the future development of IMT-2000 and systems beyond IMT-2000 taking into account the results of ITU-R studies...”. According to the agreed guidelines the methodology is technology neutral and generic. This means that the calculations focus on “future development of IMT-2000” and on “Systems beyond IMT-2000” without addressing individual technologies separately. The methodology (Recommendation ITU-R M.1768) also has the “flexibility to handle both emerging technologies, and well characterized systems such as those defined in Recommendation ITU-R M.1457”. This implies that the technical characteristics are defined on a generic level.

Furthermore, the methodology needs to:

- produce results in a manner that is easily understandable and credible;
- be implementable and verifiable within the available time scales;
- be no more complex than is justified by uncertainty of the input data.

The first conclusion is that a suitable, technology neutral and simplified approach would be to have the technologies grouped rather than having the need to handle all, (possibly tens of) technologies individually.

The second conclusion is that in order to cover the scope of agenda item 1.4, there is a requirement for the RAT groups on the “Future developments of IMT-2000” and “Systems beyond IMT-2000”.

In addition there is a need to take other RAT groups into account as “service functionalities in fixed, mobile and broadcasting networks are increasingly converging and inter working” (Resolution 228, Rev.WRC-03). This means that such networks can increasingly cover overlapping service types. Therefore, services and traffic of other relevant converging technologies must be taken into account. However, the intention of WRC-07 agenda item 1.4 is not to calculate the spectrum requirements of the other technologies, but to focus on those mentioned in the agenda item 1.4 text.

The third conclusion is therefore, that the traffic distribution to the relevant other RAT groups must be taken into account, and to do so, the other relevant RAT groups need to be defined. This will be addressed in the next section.

Finally, the RAT grouping will ease the processing of input data. Traffic data originating from service and market predictions will be needed as inputs to the methodology. It can be assumed that the predicted traffic can be distributed with reasonable accuracy to relevant RAT groups but not realistically down to individual RATs, irrespective whether the distribution will be done in the processing of the market data or by the methodology itself.

Concerning the required radio parameters, defining the radio parameters for a few RAT groups is expected to be much more feasible than for tens of separate RATs.

4.2 RAT groups

The RAT groups are not technology specific and are defined as the following:

- *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:* Systems beyond IMT-2000 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 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 Recommendation ITU-R 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 within 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. Systems beyond IMT-2000 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 systems beyond IMT-2000 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 systems beyond IMT-2000 are identified to have a relationship with RLANs. It can be expected that existing RLANs will share a portion of the relevant total traffic. WRC-03 identified globally common spectrum for RLANs, 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 and 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 (P-MP) services that cover part of the total mobile market.

4.3 Usage of RAT groups and radio parameters

4.3.1 Usage of RAT groups

The handling of each RAT group is identified in the spectrum calculation methodology. In the spectrum calculation methodology, there are two stages that are related to RAT groups. The first is the stage for distributing the calculated traffic amount to possible RAT groups. The second is the stage for calculating the required spectrum from amount of distributed traffic for future development of IMT-2000 and systems beyond IMT-2000. Thus, there are two types of RAT groups in the spectrum calculation methodology:

- Type a):* RAT group for which the spectrum requirements are to be calculated (this type of RAT group is considered through the whole stages in the spectrum calculation methodology);
- Type b):* RAT group which takes part of the total predicted traffic (this type of RAT group is considered only in the stage of traffic distribution among RAT groups).

RAT Groups 1 and 2 are considered as the first type in the spectrum calculation methodology. Required spectrum is calculated for RAT Groups 1 and 2. The spectrum that has already been identified at WARC-92 and WRC-2000 should be subtracted from the overall required spectrum for future development of IMT-2000 and systems beyond IMT-2000 in order to avoid a double count of the spectrum demand.

RAT Groups 3 and 4 are considered as the second type in the spectrum calculation methodology, for which only the amounts of traffic that are distributed to them are considered.

The traffic distribution to RAT groups needs to consider the availability and capabilities of the RAT groups in each service environment. Market predictions can provide a first indication which service categories each RAT group can support. The final distribution of traffic to RAT groups may be derived in the methodology by considering both market data and radio characteristics.

4.3.2 Usage of radio parameters for each RAT group

The full set of required radio parameters needs to be provided for the RAT Groups 1 and 2. For Groups 3 and 4 the parameters related to the spectrum demand calculation are not required. However, parameters needed in the distribution of traffic are required to the extent necessary to enable distribution of traffic to RAT groups.

5 Radio aspects relevant to spectrum requirements

5.1 General consideration

It is expected that IMT-2000 and its enhancements will continue to operate in the bands identified by WARC-92 and WRC-2000 by the time the systems beyond IMT-2000 are deployed. To fulfil the framework for systems beyond IMT-2000, it is envisaged that further spectrum may be needed in addition to that identified for IMT-2000 at WARC-92 and WRC-2000. The new capabilities for mobile access and nomadic/local wireless access have different objectives for mobility and bit rate, for which different frequency ranges may be appropriate. For new mobile access capability, data rates higher than IMT-2000 may result in a smaller cell size. This would increase the number of base stations required and hence the deployment cost. It would therefore be preferable for the frequency bands that support higher bit rate with the wide area mobility capability of systems beyond IMT-2000 to be reasonably close to the bands already identified for IMT-2000. There is also a need to address, in accordance with Resolution 228 (Rev.WRC-03), the usage of frequencies below those identified for IMT-2000 in RR No. 5.317A for the future development of IMT-2000 and systems beyond IMT-2000, notably assessing their advantages and disadvantages. Those studies should take into consideration, in particular, the needs of developing countries and countries having large territories and low teledensities. By including, for example, use of frequencies below those currently identified for IMT-2000 and use of the satellite component of IMT-2000 for suitable coverage of these countries.

IMT-2000 is already being enhanced (e.g., towards IP-based networks and to offer bit rates up to over 10 Mbit/s under favourable conditions). These initial enhancements, for which standards are already being developed, will be followed by further enhancements that could increase the peak aggregate useful data rate up to approximately 30 Mbit/s under favourable conditions. IMT-2000 and its enhancement should support low to high mobility since these systems are mainly to be deployed in the cellular environment. A new mobile access is envisaged to handle a wide range of supported data rates according to economic and service demands in multi-user environments, with target peak data rates of up to approximately 100 Mbit/s. Low to high mobility should be supported since a new mobile access would be deployed both in cellular and hotspot environments. A new nomadic/local area wireless access is predicted to handle wide range of supported peak data rates up to 1 Gbit/s. Low mobility should mainly be supported since the new nomadic/local area wireless access would be deployed in a hotspot environment.

In Recommendation ITU-R M.1390, radio operation environments have been defined as areas exhibiting common propagation conditions. The radio operation environments were categorized into four environments:

- rural;
- suburban;
- urban;
- dense urban.

Since the radio operation environments considered only IMT-2000, common service conditions were exhibited in each radio environments. In the future development of IMT-2000 and systems beyond IMT-2000, however, environments that are defined as areas exhibiting common service conditions would be important. Therefore, service usage patterns and teledensity were introduced for the spectrum calculation methodology.

The current terminology is briefly introduced in the following.

The service usage patterns are defined as areas representing common usage conditions and can be classified to:

- home;
- office;
- public area.

The teledensity is defined as area representing locality and population density and can be classified to:

- dense urban;
- suburban;
- and rural.

Service usage patterns and teledensity should be used as combined environments that can be redefined as service environments. Service environments can be defined as areas exhibiting common service conditions.

The number of service environments can be reduced taking into account the commonality and nature of service application usages and six classes are defined:

- dense urban/home;
- dense urban/office;
- dense urban/public area;
- suburban/home;
- suburban/office and public area;
- rural.

The radio environments defined as areas representing common propagation conditions should separately be treated from service environments since typical deployment scenario and technical requirements for radio access technique group (RAT group) may be discussed from a technical view point.

The radio environments may be categorized into:

- macro cell;
- micro cell;
- pico cell;
- hot spot.

The definition of the radio environment is the most relevant element of those described above. As such the Radio environments will be addressed in detail in § 6 of this Report.

5.2 Radio parameters

Section 5.2.1 describes the required parameters which are necessary to calculate the spectrum needs. Tables 1a to 1d show also the initial recommended values for the parameters. The justifications for the values can be found in Annexes 2, 3, 4 and 5.

Section 5.2.2 lists additional parameters which have been input by various proponents. These additional parameters provide additional radio related information. The additional parameters may provide additional assistance in calculating not only spectrum requirements, but propagation characteristics, radio characteristics related to services, and technical characteristics. Therefore they may be useful in further work on radio aspects, even though they are not needed in the current

spectrum requirement calculation methodology, and thus not relevant for the WRC-07 related preparatory work.

Additional parameters may be assigned to three categories:

- Propagation (P);
- Service (S);
- Technical (T).

Rational of the categorization is given in § 5.5.

Most of the values for the additional parameters are still undefined and the values can be considered at the later stages of the work.

5.2.1 Radio parameters required for spectrum calculation methodology

These parameters are used in the spectrum requirement calculation methodology and are briefly defined in the following sub sections. The parameters and the initial recommended values for the parameters are shown in Tables 1a to 1d. The justifications for the values are shown in the Annexes to this Report. One parameter value per radio environment and RAT group is considered. The parameters should represent the RATs belonging to the group in a reasonable manner.

TABLE 1a
Required radio parameters for RAT Group 1*

Attribute	RAT Group 1				
	Value				
	Unit	Macro cell	Micro cell	Pico cell	Hot spot ⁽¹⁾
Application data rate	Mbit/s	1	1	2.5	–
Supported mobility classes		Stationary/ pedestrian, low, high,	Stationary/ pedestrian, low	Stationary/ pedestrian	–
Carrier bandwidth (CBW)	MHz	Up to 5	Up to 5	Up to 5	–
Guardband between operators	MHz	0	0	0	–
Minimum deployment per operator per radio environment (where $n = 1$ or 2)	MHz	$n \cdot \text{CBW}$	$n \cdot \text{CBW}$	$n \cdot \text{CBW}$	–
Number of overlapping network deployment	#	5	5	5	–
Possibility to flexible spectrum usage (FSU)	Boolean	No	No	No	–
FSU margin	Multiplier	1	1	1	
Area spectral efficiency	bit/s/Hz/ cell	0.4	0.4	0.7	–
Area spectral efficiency for multicasting	bit/s/Hz/ cell	0.2	0.2	0.4	–

TABLE 1a (*end*)

Attribute	RAT Group 1				
	Value				
	Unit	Macro cell	Micro cell	Pico cell	Hot spot ⁽¹⁾
Typical operating frequency	MHz	< 2 700	< 2 700	< 2 700	–
Support for multicast	Boolean	Yes	Yes	Yes	–

* The values presented in Table 1a are not applicable to the scenario at large areas with low teledensity coverage. These values should be further estimated.

⁽¹⁾ Hot spot radio environment is not relevant for RAT Group 1.

TABLE 1b

Required radio parameters or RAT Group 2

Attribute	RAT Group 2				
	Value				
	Unit	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
CBW	MHz	25-50	25-100	100	100
Guardband between operators	MHz	0	0	0	0
Minimum deployment per operator per radio environment	MHz	50-100	50-100	100	100
Number of overlapping network deployment ⁽¹⁾	#	1-4	1-4	1-4	1-4
Possibility to FSU	Boolean	Yes	Yes	Yes	Yes
FSU margin	Multiplier	1	1	1	1
Area spectral efficiency	bit/s/Hz/cell	2-4	2-5	3-6	5-10
Area spectral efficiency for multicasting	bit/s/Hz/cell	1-1.5	1-2.5	1.5-3	2.5-5
Typical operating frequency	MHz	< 6 000	< 6 000	< 6 000	< 6 000
Support for multicast	Boolean	Yes	Yes	Yes	Yes

⁽¹⁾ This parameter needs to be determined during the estimation process.

TABLE 1c

Required radio parameters for RAT Group 3

Attribute	RAT Group 3				
	Value				
	Unit	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 – Macro cell and micro cell are not considered for RAT Group 3.

TABLE 1d

Required radio parameters for RAT Group 4

RAT Group 4		
Attribute	Unit	Macro cell
Application data rate	Mbit/s	2
Supported mobility classes		All (Stationary/pedestrian, low and high)

NOTE 1 – Only macro cell is considered for RAT Group 4.

5.2.1.1 Application data rate

This parameter is used by methodology for distributing the traffic. It represents a bit rate which is available for applications in a particular cell type. It may be smaller than the available peak bit rate and may not be available throughout the whole cell.

5.2.1.2 Supported mobility classes

The maximum velocity is determined by Doppler frequency and handover initiation and execution times. For macro cells the Doppler frequency limits the velocity and the cell edge user data rate will decrease once the velocity exceeds a certain limit. This limit is around 120 km/h for IMT-2000.

In particular, for small cells, the minimum time a user stays 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 Recommendation ITU-R M.1768, this parameter will affect the distribution of traffic to the radio environments and RAT groups. Traffic is classified into mobility classes.

The methodology defines the mobility classes (MC) stationary/pedestrian, low and high. These mobility classes correspond with the following velocities:

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

5.2.1.3 Carrier bandwidth (MHz)

The carrier bandwidth is used in the spectrum requirements method to adjust the final spectrum requirements. The calculated spectrum requirement for each RAT group is an integer multiple of the carrier bandwidths. The carrier bandwidth is equal to carrier separation thus it already includes a guardband between carriers inside one operator network. The carrier bit rate should support the promised achievable bit rate of the RAT group. Inside RAT group the carrier bandwidth may be different for different RATs and the parameter value should represent the largest RAT individual carrier bandwidth, in order not to under estimate the spectrum demand.

5.2.1.4 Guardband between operators (MHz)

This parameter is determined by technology specific characteristics like the filter properties and the level of tolerated adjacent channel interference. In case some techniques require guardband between the spectrum allocations of different operators this is added in the calculated spectrum requirement. Guardbands required between carriers of the same operator are assumed to be contained in the CBW parameter.

5.2.1.5 Minimum deployment per operator per cell type (MHz)

This is defined to be a minimum amount of spectrum needed for one operator to build a practical working network per radio environment, including e.g. the needed frequency reuse and guardband between carriers of one operator. Therefore this parameter is typically an integer multiple of the carrier bandwidths.

5.2.1.6 Number of overlapping network deployments

In the spectrum requirement calculation method the number of operators in the same geographical area is used to calculate the total required spectrum. The capacity requirement of one RAT group to serve the total traffic of this RAT group, calculated according the spectrum requirement method, is distributed equally to all these operators (i.e. deployments). This enables to take the minimum needed spectrum for deployments and guard spectrum bands between operators into consideration.

5.2.1.7 Possibility to FSU (Boolean)

The spectrum requirement method provides the possibility of taking into account time-sharing of spectrum by different RAT groups. A common spectrum requirement is calculated for all RAT groups that support FSU. Thus, if the characteristic RATs inside the RAT group in the spectrum allocation area can utilize FSU, this parameter is true.

5.2.1.8 FSU Margin

FSU Margin is needed to indicate the gain from the possible flexible spectrum use. It is a multiplier, and in the case of no FSU it should be 1. If the FSU is possible in the RAT group then the FSU margin is greater or equal to 1.

5.2.1.9 Area spectral efficiency

The area spectral efficiency is used in the spectrum requirement calculations to convert the capacity requirements in terms of bit/s/Hz/cell to the spectrum requirements. 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 the spectral efficiency might be the same for several teledensities, it is possible that spectral efficiency may also vary between teledensities, thus the spectral efficiency for different teledensities may be needed.

5.2.1.10 Area spectral efficiency for multicasting (bit/s/Hz/cell)

The spectrum efficiency is generally different for multicasting than for “normal” point-to-point communication. If there is support for multicast, values for this parameter have to be provided.

5.2.1.11 Typical operating frequency

This parameter is not needed by the spectrum requirement method directly, but will be essential in interpreting the spectrum demands that will be the outcome of calculations, and in the process of identifying candidate frequency bands. This parameter needs to reflect the assumptions on propagation conditions that have an effect on the cell radius and spectral efficiency parameters, for example. It is suggested that the suitable frequency range should be below 6 GHz.

5.2.1.12 Support of multicast

The parameter is meant to indicate the capability of this RAT group to support P-MP mode. For this multicast mode, the methodology assumes that the capacity requirement is independent of the number of serviced users.

5.2.2 Additional parameters

The additional parameters may be utilized for spectral efficiency calculations.

5.2.2.1 Path loss factor

Mean path loss is calculated by a function of distance, d . The function is simply presented as $K + \chi_d \log(d)$, where K and χ_d are propagation law constant including dependency to carrier frequency and path-loss exponent for typical radio environments, respectively. Pathloss should be taken into account for determining cell area to be covered and suitable frequency range. Variation in received signal level should be considered in calculating the average spectrum efficiency.

5.2.2.2 Slow fading distribution

Slow fading is due to shadowing and scattering. The slow fading variation is considered to be log-normally distributed with a standard deviation of σ dB in typical radio environments. Slow fading distribution should also be taken into account to discuss cell deployment and requirement for handover.

5.2.2.3 Fast fading distribution

Fast fading is due to multipath propagation. The fast fading variation is typically Rayleigh distributed or Rice distribution. Supported maximum Doppler frequency is determined by supported terminal velocity and suitable frequency range to be operated. Requirement for radio packet size is much smaller than coherence time which is characterized by fading variation. Techniques to compensate degradation due to fading variation should be taken into account to determine supported peak bit rate and spectrum efficiency.

5.2.2.4 Service channel bit rate

Service channel bit rate is determined for each service category. Supported service channel bit rate mainly depends on propagation characteristics.

5.2.2.5 Target deployment environment

Target deployment environment of each radio environment should be discussed. Location of base station, surrounding obstacles, mobility, and etc. affect propagation characteristics. The applicability of highly efficient transmission technology depends on propagation characteristic. Cell structure (multi-cell or isolated area) may determine the requirements for handover.

Deployment scenario is considered to discuss cell area, supported bit rate and spectrum efficiency, required carrier bandwidth, required number of channels, required guardband, and traffic distribution within RAT group.

5.2.2.6 Support of horizontal and vertical handover

Requirements for handover between cells of the same RAT group and handover between different RAT groups are determined taking into account the deployment scenario.

5.2.2.7 Modulation scheme

The process of varying certain parameters of a digital code signal (carrier) may be achieved, through digital signal processing, in accordance with a digital message signal, to allow transmission of the message signal through IF and RF channels, followed by its possible detection.

Modulation can be categorized as data modulation and spreading modulation. Data modulation explains how data can be mapped to the in-phase branch and quadrature-phase branch. Spreading modulation explains how in-phase branch data and quadrature-phase branch data are spread by channelization code and scrambled by scrambling code

5.2.2.8 Multiple antennas

Applicability of multiple antenna techniques to increase capacity, bit rate and spectrum efficiency should be considered.

5.2.2.9 C/N requirement for peak bit rate

Required C/N ratio to achieve transmission with peak bit rate.

5.2.2.10 Channel coding and interleaving

Describes the requirements for channel coding and interleaving under the radio environment and spectrum efficiency and quality requirements of the various services.

5.2.2.11 Delay parameter of propagation

Delay spread and delay per path.

5.2.2.12 Doppler spectrum

Mobility characteristics and frequency define the Doppler spectrum. For example, maximum Doppler shifts range from approximately 50 Hz to 1.2 kHz when the carrier frequency is 5 GHz.

5.2.2.13 Multiple access technology

Describes the requirements for multiple access technology that has major impact on the design of the radio interface.

5.2.2.14 Network topology

Network structure (cellular, ad-hoc/multi-hop, etc.). Hexagonal cellular/circular area/irregular area.

5.2.1.15 Achievable cell edge user bit rate (bit/s)

This parameter should be given for the deployment of hot spot (isolated cells), where typically higher values are achievable, and for other, non-isolated cells, where multiple cells together provide geographical coverage. The values can be determined based on radio link and system simulations (literature/new simulations).

This parameter is defined in the network taking the propagation conditions, interference conditions and network overheads into account and is thus lower than the peak bit rate.

The peak data rate achieved in cellular systems is a function of a number of factors that include propagation conditions and interference. These two factors heavily influence the performance of any cellular system.

There are two kinds of interference in cellular systems; intracell interference and intercell interference. The former is always present, but the latter depends upon the multiple access method. Intercell interference can be reduced by sectorization and/or frequency reuse.

In a highly loaded system, the interference will reduce the peak bit rates achieved, especially at the cell edge, but the extent of this depends upon the numbers of sectors and frequency reuse scheme employed.

The available cell edge user data rate is in any event implicitly dependent on how the operator chooses to distribute the available peak sector data rate amongst users in the sector or cell and how this translates to the peak data rate achieved by individual users at any instant in time given the varying traffic conditions over time.

5.2.2.16 Spatial channel characteristics

Angle spread, angles of departure, angle of arrival, and power azimuth spectrum per path, etc.

5.2.2.17 Supported peak bit rate (Mbit/s)

From the technical point of view, the supported peak bit rate $B_{rat,p}$, is determined by taking into account the radio propagation characteristics and cell deployment. Applicability of highly efficient transmission techniques such as adaptive modulation or multi antenna transmission should be considered. The typical peak bit rate currently achieved in RAT Group 1 is approximately 14 Mbit/s. It should also be noted that target peak bit rates for RAT Group 2 are approximately 100 Mbit/s and 1 Gbit/s with high mobility and low mobility, respectively, as described in Recommendation ITU-R M.1645. From the service point of view, the supportable service type or application usage scenario depends on $B_{rat,p}$.

5.2.2.18 Radio frame size

Required radio frame size, $\beta_{rat,p}$, is determined by taking into account the propagation characteristic. $\beta_{rat,p}$ should be much shorter than the coherence time in order for the radio channel to be quasi-static within a frame. The coherence time depends on mobility and carrier frequency. Typical radio frame size in RAT Group 1 is 2 ms. Since the bit rate in RAT Group 2 is much higher than that in RAT Group 1, the radio frame size is expected to be much shorter.

5.2.2.19 One-way air interface delay (ms)

This parameter is assumed to exclude the core network delay and in packet-based systems is measured from on the IP layer to IP layer. Thus the delay includes the queuing and transmission times. For circuit switched (CS) services the air interface delay only includes delays on layer 1 and 2.

5.3 Spectrum efficiency

5.3.1 Area spectral efficiency

For each RAT group an area spectral efficiency matrix needs to be estimated. The area spectral efficiency of each RAT group in each radio environment can be estimated using average spectrum efficiency, which is determined taking into account propagation characteristics, interference considerations and typical deployment scenarios and technical requirements for technical characteristics.

In the spectrum calculation methodology, the required spectrum in each radio environment for each RAT group is calculated by using area spectrum efficiency.

The area spectral efficiency is calculated from the mean data throughput achieved over all users, which are homogeneously distributed in the area of the radio environment, on the IP layer for packet switched services, and on the application layer for circuit switched services, for fully loaded radio networks.

The recommended area spectral efficiency values for both RAT Group 1 and 2 are shown in Tables 1a and 1b.

5.3.2 Required spectrum calculation

Required unadjusted spectrum $F_{rat,p}$ in radio environment P (Rep) for RAT Group rat is calculated by dividing the required system capacity per cell area by net system capability as,

$$F_{rat,p} = C_{rat,p} / \eta_{rat,p}$$

5.3.3 Technical issues affecting spectral efficiency

Multiple antenna techniques at the base station transmitter can be used to enhance performance metrics such as throughput, peak rate, and coverage by providing for example diversity gain, spatial multiplexing (SM), and/or spatial division multiple access (SDMA) gain. Diversity provides multiple independent realizations of a fading channel to improve link performance. Under SM, parallel data streams are transmitted using the same spectral resources to a single user to improve its link rate. And under SDMA, the base station transmits simultaneously to multiple users using the same spectral resources but over separate spatial channels to increase the system throughput. For further details see Report ITU-R M.2040.

Spatial multiplexing

SM requires multiple antennas at the receiver in order to demodulate the parallel data streams. Using multiple transmit and receive antennas per terminal, higher spectral efficiencies can be achieved.

For example, by increasing spectral efficiencies from 1 to 4 bit/s/Hz/cell, a 100 Mbit/s peak data rate can be achieved in 25 MHz bandwidth or 100 MHz bandwidth can achieve a 400 Mbit/s peak rate.

Example simulation results are shown in Annex 5.

Spatial division multiple access

While SM is effective for increasing the peak data rate per user, SDMA is more effective for increasing the spectral efficiency in terms of throughput per cell. Using the same antenna resources, SDMA has a much higher system-level throughput than SM. However, the peak rate per user under SDMA does not increase compared to the single-antenna transmitter case.

Spatial multiplexing using MIMO systems

An explanation and schematic of a multiple input multiple output (MIMO) system is shown in [Gesbert *et al*, 2003]. MIMO systems provide a substantial increase in spectrum efficiency and hence capacity [Foschini, 1996; Foschini *et al*, 1998]. In a MIMO system a high rate data stream is converted to several low rate streams which are then transmitted over multiple transmit antennas. At the receiver the spatial interference from the received data is removed, and the bit streams are multiplexed back to the high rate stream.

Increases in spectral efficiency can be shown to be linear with respect to the number of transmit and receive antennas, e.g. if the spectrum efficiency of the coding and modulation scheme employed per