

International Telecommunication Union

**ITU-R**  
Radiocommunication Sector of ITU

**Report ITU-R M.2290-0**  
(12/2013)

**Future spectrum requirements  
estimate for terrestrial IMT**

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



International  
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*Note: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

*Electronic Publication*  
Geneva, 2014

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## REPORT ITU-R M.2290-0

**Future spectrum requirements estimate for terrestrial IMT**

(2013)

**1 Introduction**

For the preparation of WRC-15 agenda item 1.1, Resolution **233 (WRC-12)** invited ITU-R to study additional spectrum requirements for International Mobile Telecommunications (IMT) and other terrestrial mobile broadband applications. Previously, ITU-R estimated the spectrum requirements for IMT in the preparatory studies for WRC-07 agenda item 1.4, the results of which are documented in Report ITU-R M.2078. Since the approval of Report ITU-R M.2078 in 2006, there have been significant advances in IMT technologies and the deployment of IMT networks. Further, traffic growth in different mobile telecommunication markets, including those of IMT networks, has been shown in Report ITU-R M.2243.

Taking into account these recent trends, this Report provides the results of new studies on estimated spectrum requirements for terrestrial IMT in the year 2020. In order to reflect the advances in technologies and the deployments of IMT networks, the spectrum requirements are calculated<sup>1</sup> using the updated methodology in Recommendation ITU-R M.1768-1. Furthermore, input parameter values to be used in this methodology have been updated from those employed in Report ITU-R M.2078 in order to reflect the recent developments in mobile telecommunication markets. It should be noted that the updated radio aspect parameters used in the methodology are contained in Report ITU-R M.2289.

The Report provides a global perspective on the future spectrum requirement estimate for terrestrial IMT. The input parameters in this Report represent a possible set of global scenarios of the future mobile traffic growth. In some countries, the calculated spectrum requirements may depend on the specific market circumstances and the regulatory conditions hence spectrum requirements can be lower than the estimate derived by lower user density settings and in some other countries, spectrum requirement can be higher than the estimate derived by higher user density settings. The methodology utilized in the Report can be used to estimate the total IMT spectrum requirements of a given country only if all the current input parameter values used in this report are replaced by the values which apply to that specific country (as described in the methodology itself).

Moreover, to date there are no reliable statistics in ITU on the use of the spectrum already allocated to terrestrial IMT by a previous WRC.

During the preparatory work of WRC-15 agenda item 1.1, national spectrum requirements in some countries were provided. For reference, those are summarized as shown in Annex 4.

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<sup>1</sup> Both a calculator containing an implementation of the methodology and a user guide providing advice on the use of the calculator and the input parameters can be found at the ITU website on the ITU-R Working Party 5D webpage.

The [spectrum requirement calculator tool for IMT \(WINNER\)](https://www.itu.int/oth/tiesonly/download.aspx?file=R0A060000580002XLSE.xls) can be found at: <https://www.itu.int/oth/tiesonly/download.aspx?file=R0A060000580002XLSE.xls>

The [user guide for the IMT spectrum requirement estimation tool](https://www.itu.int/oth/tiesonly/download.aspx?file=R0A060000580001MSWE.docx) can be found at: <https://www.itu.int/oth/tiesonly/download.aspx?file=R0A060000580001MSWE.docx>

## 2 Related ITU-R Recommendations and Reports

Recommendation ITU-R M.1768-1 – Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications.

Report ITU-R M.2072 – World mobile telecommunication market forecast.

Report ITU-R M.2074 – Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000.

Report ITU-R M.2078 – Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced.

Report ITU-R M.2243 – Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications.

Report ITU-R M.2289 – Future radio aspect parameters for use with the terrestrial IMT spectrum estimate methodology of Recommendation ITU-R M.1768-1.

### List of acronyms and abbreviations

DL	Downlink
IMT	International Mobile Telecommunications
QoS	Quality of Service
RATG	Radio Access Technology Group <sup>2</sup>
RLAN	Radio Local Area Network
SC	Service Categories
UL	Uplink

## 3 Methodology

Recommendation ITU-R M.1768-1 (Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications) reflects certain recent advances in IMT technologies and the deployment of IMT networks:

- introduction of spectrum sharing between the macro and micro cell layers in IMT-Advanced;
- introduction of a new spectrum granularity parameter for IMT systems.

The updated methodology provides the spectrum requirements of IMT as a whole, and divided between two radio access technique groups (RATGs):

- RATG 1: Pre-IMT systems, IMT-2000 and its enhancements;
- RATG 2: IMT-Advanced.

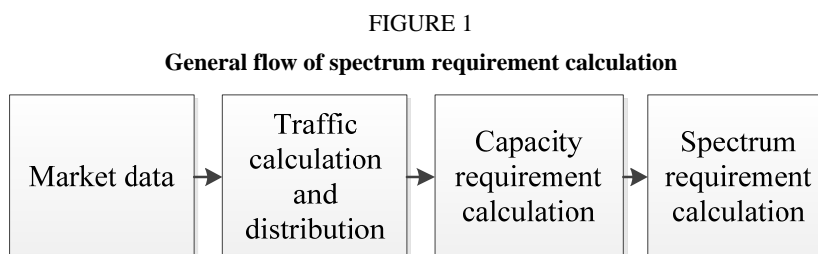
The spectrum requirement estimation methodology follows a technology-neutral approach and takes into account market, technology and deployment-related information. The following parts provide brief explanations of the methodology as set out in Recommendation ITU-R M.1768-1.

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<sup>2</sup> Though Recommendation ITU-R M.1768 defines RATG as “Radio Access Technique Group,” the term “Radio Access Technology Group” is the one which is more commonly used.

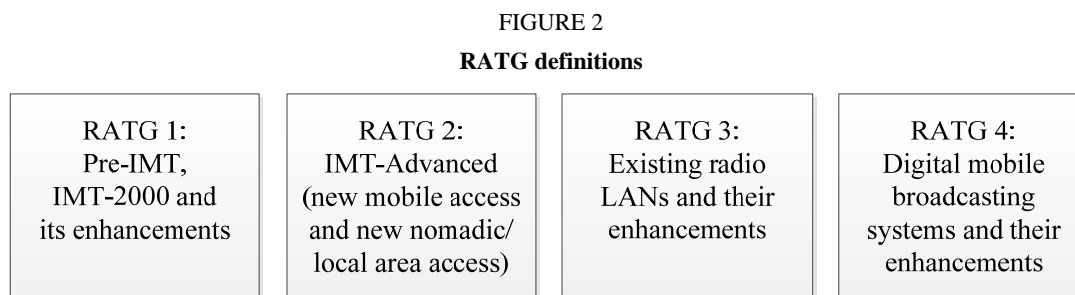
### 3.1 Methodology flow chart

The general *flow chart* of the methodology in Recommendation ITU-R M.1768-1 consists of nine consecutive steps which are grouped into four main blocks as shown in Fig. 1. The methodology starts with an analysis of market data, moves on to calculate and distribute traffic, and then calculates the capacity required, before concluding with an estimate of the spectrum requirements.



### 3.2 Definitions used in the methodology

Recommendation ITU-R M.1768-1 uses the *radio access technology (previously technique) group* (RATG) definitions from Report ITU-R M.2074, which are summarized in Fig. 2. Report ITU-R M.2074 also presents justification for using the RATG approach. It should be noted that the method in Recommendation ITU-R M.1768-1 estimates the spectrum demand for RATGs 1 and 2 only, but not those of RATG 3 (RLAN) and RATG 4. While it is true that the method takes into account the global mobile telecommunications traffic carried by different mobile systems such as IMT and RLAN, nevertheless the spectrum requirements are calculated only for IMT. Note that this methodology can be used to estimate the total IMT spectrum requirements of a specific country only if all the current (global) input parameter values are replaced by the values which apply to that specific country (as described in the methodology itself).



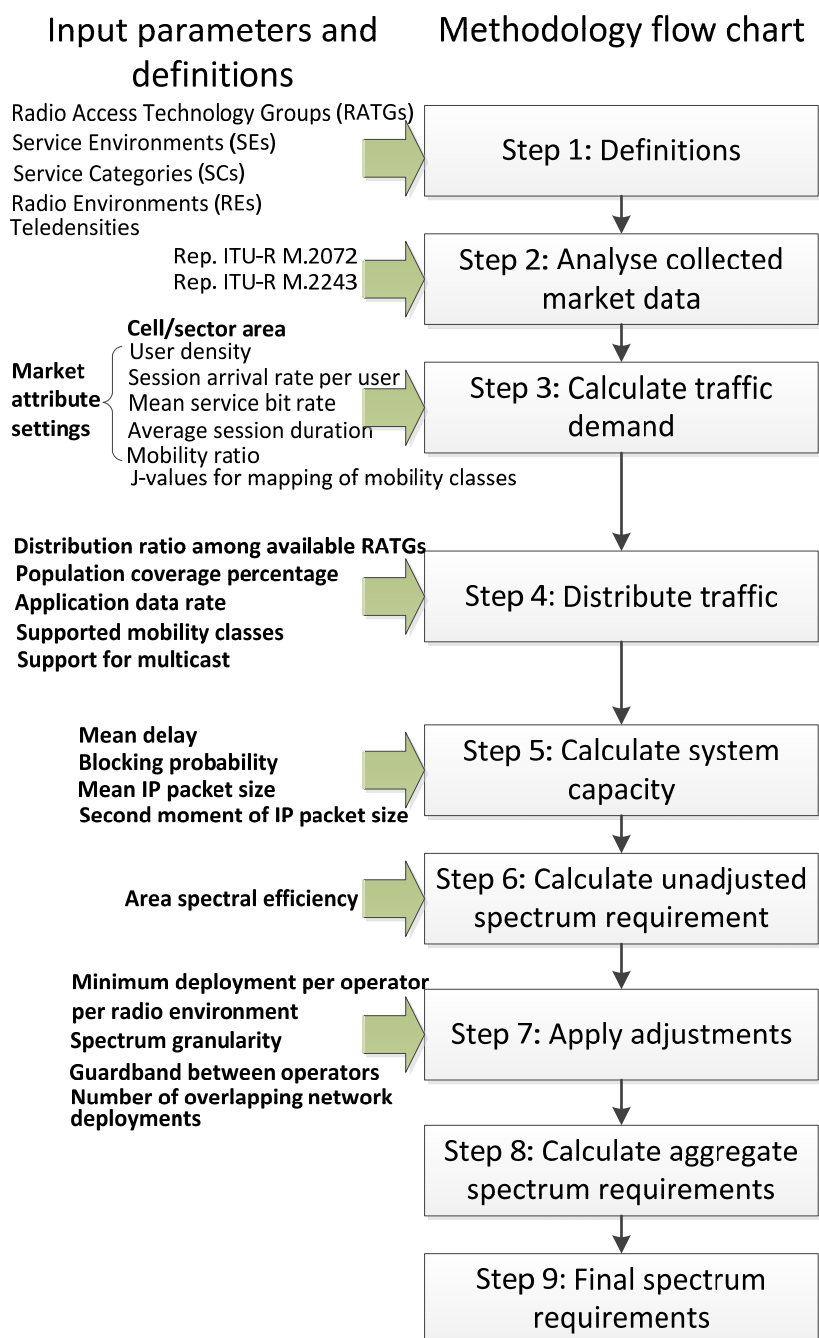
The *service categories* of Recommendation ITU-R M.1768-1 are defined using service types (super-high multimedia high multimedia, medium multimedia, low rate data and low multimedia, and very low rate data), and traffic classes (conversational, streaming, interactive, and background) from Recommendation ITU-R M.1079-2. Furthermore, the service categories (SCs) are divided into reservation-based and packet-switched service categories depending on the transmission scheme assumed in their delivery. The *service environment* definitions in Recommendation ITU-R M.1768-1 are based on service usage patterns (home, office, and public area) and teledensities (dense urban, suburban, and rural).

The *radio environment* definitions in Recommendation ITU-R M.1768-1 include macro cell, micro cell, pico cell and hot spot cell layers. The radio environments are generic definitions that are applicable to the different RATGs. The definitions are based on Report ITU-R M.2074, where a detailed description of the layered approach (and the different cell types) is given.

### 3.3 Calculation algorithms

Figure 3 summarizes the steps of the calculation algorithm employed in Recommendation ITU-R M.1768-1 in conjunction with relevant input parameters (detailed descriptions of these parameters are provided in § 4). The methodology starts from market studies that characterize all of the traffic carried by IMT and other mobile systems, corresponding to Steps 2-3. In Step 4, the total traffic obtained from the market studies is distributed among different radio environments (cell layers) and RATGs according to factors such as traffic characteristics (required data rates and user mobilities), RATG capabilities (supported data rates, available cell types and their coverage), etc. The system capacity required to carry the offered traffic is then calculated in Step 5 using separate capacity calculation algorithms for reservation-based traffic and packet-based traffic respectively. Initial spectrum estimates are obtained from the capacity requirements by dividing the latter by the spectral efficiencies (Step 6). Then, adjustments are made to take into account network deployments with the spectrum requirements being aggregated over the relevant deployments (Steps 7-8). Finally, the methodology outputs the overall spectrum requirements of RATG 1 and RATG 2, which collectively denote IMT systems (Step 9).

FIGURE 3  
Steps of calculation algorithm and relevant input parameters



The main calculation algorithms in Recommendation ITU-R M.1768-1 include the traffic calculation algorithm, the traffic distribution algorithm, the capacity calculation algorithm, and the spectrum requirement calculation algorithm which are reviewed below:

### Step 3

The *traffic calculation algorithm* is used to calculate the traffic demand by service categories and service environments using the market data from Report ITU-R M.2072 and processing it into the format used in Recommendation ITU-R M.1768-1.

The traffic related input parameters for which the calculation is done include user density, session arrival rate per user, average session duration, mean service bit rate, and mobility ratios. The calculations are done separately for the uplink (UL) and the downlink (DL) directions.

#### Step 4

The *traffic distribution algorithm* calculates traffic distribution ratios that determine which proportion of the traffic in each service category in each service environment goes to each available radio environment and RATG. The traffic distribution algorithm first determines the possible combinations of service categories, service environments, radio environments and RATGs based on the data rate and mobility requirements of the service categories and the capabilities and availability of radio environments and RATGs in different service environments. If all traffic can be distributed, the sum of the traffic distribution ratios over the radio environments and RATGs for a given service category in a given service environment in case of unicast traffic becomes equal to one. The traffic distribution algorithm first distributes the traffic among available radio environments and then among available RATGs. The distribution to radio environments is initiated by allocating as much traffic to small cells as possible and then proceeding to larger cells. The split among the available RATGs in a given radio environment is done through the input parameter “distribution ratio among available RATGs”.

#### Step 5

The *capacity calculation algorithm* is used to estimate the required system capacity to support the forecasted traffic in the radio environments of RATG 1 and RATG 2 in different teledensities. The capacity calculation algorithm includes two distinct approaches depending on the transmission scheme deployed for the service category. For reservation-based service categories, the capacity calculation algorithm uses the multi-dimensional Erlang-B formula, which is an extension of the well-known Erlang-B formula using blocking probability as the QoS indicator. The algorithm allows the system to consider multiple traffic classes with class-specific blocking requirements and simultaneous occupation of several channels by each call. For packet-switched service categories, the capacity calculation algorithm uses an M/G/1 queuing model with non-pre-emptive priorities where a single server is used to serve the arriving packets of different service categories based on their priorities. The mean delay is used as the QoS indicator.

#### Steps 6-9

The *spectrum requirement calculation algorithm* calculates the raw spectrum requirements from the capacity requirements using spectral efficiency values. It then applies adjustments to the raw spectrum requirements by taking into account the minimum amount of spectrum that is needed for each radio environment in each RATG, the number of overlapping network deployments and possible guard bands. The spectrum requirements of the different radio environments (cell layers) are aggregated over the radio environments assuming that macro cells and micro cells require their own spectrum in RATG 1 but pico cells and hot spots can share the spectrum with each other, resulting in a total of three different deployment layers, each requiring their own frequency channel. Recommendation ITU-R M.1768-1 assumes that there are three cell layers in RATG 1 that require their own spectrum while frequency reuse equal to one is assumed for each specific cell layer so that all macro cells, for example, use the same frequency.

The recent development of heterogeneous networks in IMT-Advanced is leading to the direction that the different cell types are capable of being deployed within the same spectrum band more efficiently than previously anticipated. Therefore the approach of three different cell layers, each with its own dedicated spectrum is considered to be inaccurate for RATG 2 in 2020.

To better reflect the recent developments in spectrum sharing between cell layers, the requirement calculation algorithm in Recommendation ITU-R M.1768-1 assumes only two separate cell layers



with their own spectrum for RATG 2, where larger cells (macro cells and micro cells) would use the same set of frequencies while small cells (pico cells and hot spots) would use another set of frequencies typically from the higher frequency bands.

### 3.4 Market and technology development

*Mobile data offloading* is an important topic in response to the growing data rate demand. Offloading in general aims at transferring data from larger cells in the cellular networks to smaller cells (including different RATGs like RATG 3 (RLAN)). The two main approaches for offloading are a) from cellular networks to RLAN and b) within the cellular networks from larger cells to smaller cells using lower power. Both of these offloading approaches are taken into account in Recommendation ITU-R M.1768-1 at the point where the traffic is distributed to different radio environments (cell types) and RATGs (IMT, RLAN etc.). The influence of mobile data offloading from large cells to small cells inside the IMT system is taken into account in the traffic distribution to radio environments, which already favours smaller cells in the traffic allocation.

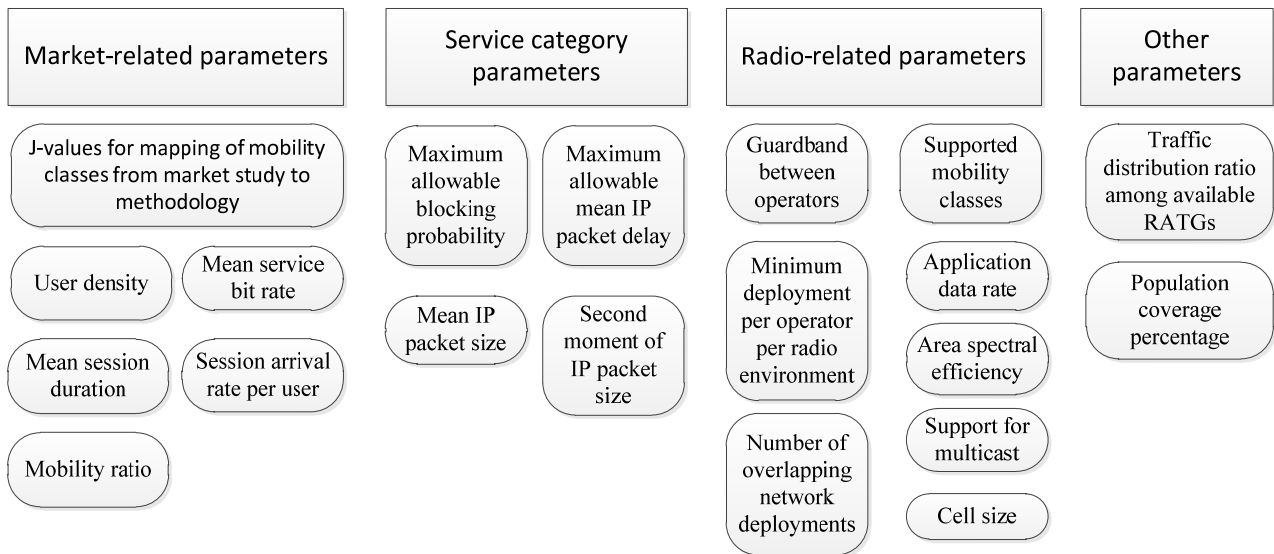
The influence of the mobile data offloading from IMT systems to RLAN corresponds to the situation in which traffic is transferred from RATGs 1 and 2 to RATG 3 in the methodology. This is done by using the parameter “distribution ratio among available RATGs” that splits the traffic of a given service category to each RATG in the case that multiple RATGs are available in the given radio environment. It should be noted that a change in this parameter value does not necessarily result in a substantial change in the final adjusted spectrum requirement as it influences the splitting of the traffic of each service category. It does not denote the overall splitting of the total traffic volume among the different RATGs but it is used to split the traffic of each service category separately in the case when there are multiple RATGs available in the given radio environment. There may be different radio environments and RATGs available for the different service categories depending on their capabilities and requirements and thus the influence of the change in this parameter value is not always directly visible.

## 4 Input parameters

The spectrum requirement estimation methodology in Recommendation ITU-R M.1768-1 uses a number of input parameters, which are summarized in Fig. 4. Here the input parameters have been categorised into market-related input parameters, service category parameters, radio-related input parameters, and other parameters.

FIGURE 4

## Classification of input parameters to the spectrum requirement estimation methodology



## 4.1 Market-related input parameters

### 4.1.1 Service category definitions

Recommendation ITU-R M.1768-1 classifies service categories (SC) into reservation-based and packet-switched based transmission schemes through which they are delivered. Conversational and streaming traffic classes are assumed to be delivered through the reservation-based transmission scheme while interactive and background traffic classes are delivered through the packet-switched transmission scheme.

### 4.1.2 Market related parameters

Market related parameters include user density, session arrival rate per user, average session duration, mean service bit rate, and mobility ratios. They are used in the calculation of the traffic demand in Step 3 in Fig. 3. Mean service bit rate is also used as an input to the capacity calculation of reservation-based service categories.

The unique values for the market parameters selected from the ranges given in Report ITU-R M.2072 are determined through percentage values (0-100). 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. The traffic calculation for reservation-based SCs is done as a multiplication of user density ( $U$ ), session arrival rate per user ( $Q$ ), and average session duration ( $\mu$ ). The traffic calculation for packet-switched SCs is done as a multiplication of user density ( $U$ ), session arrival rate per user ( $Q$ ), mean service bit rate ( $R$ ), and average session duration ( $\mu$ ).

Additionally, for market parameter “mobility ratios”, three scenarios are considered: lowest (1), medium (2) and highest mobility scenario (3).

Recommendation ITU-R M.1768-1 defines a splitting factor “ $J$ -value” for mapping of mobility classes from the market studies in Report ITU-R M.2072 to the mobility classes defined and used in the methodology in Recommendation ITU-R M.1768-1, since the mobility classes and their definitions were different (in Report ITU-R M.2072). The  $J$ -value is used to split the traffic of “high” mobility class from market studies into the “low” and “high” classes so that the fraction  $J$  of the traffic goes to class “low” and the fraction  $(1-J)$  goes to traffic class “high”.

The recent mobile telecommunication market developments in Report ITU-R M.2243 indicate that forecasts prior to WRC-07 might have underestimated the actual market development. The actual market-related parameters values should thus be higher than those used in Report ITU-R M.2078. In order to reflect the increasing traffic demand, new updated market attributes for the lower user density and higher user density settings are provided, where the following rationale behind these figures aims to justify the selection of these parameters.

The use of two market settings, lower and higher user density settings, permits modelling of the differences in markets between different countries. The two settings will result in two final spectrum requirements for IMT systems and the needs of the different countries could lie between these two extremes. This approach was taken in Report ITU-R M.2078 where the user density was considered to be the main differentiator when considering the different market settings. Session arrival rate per user, mean service bit rate, and average session duration are expected to possess similar characteristics in the different deployments.

Moreover, the traffic (for packet-switching) is calculated as the multiplication of these four market parameters and if all are changed at the same time, the resulting traffic calculation may become unnecessarily complicated. Therefore, the user density is the only market setting parameter that differs in the different market settings (i.e. lower and higher user density settings).

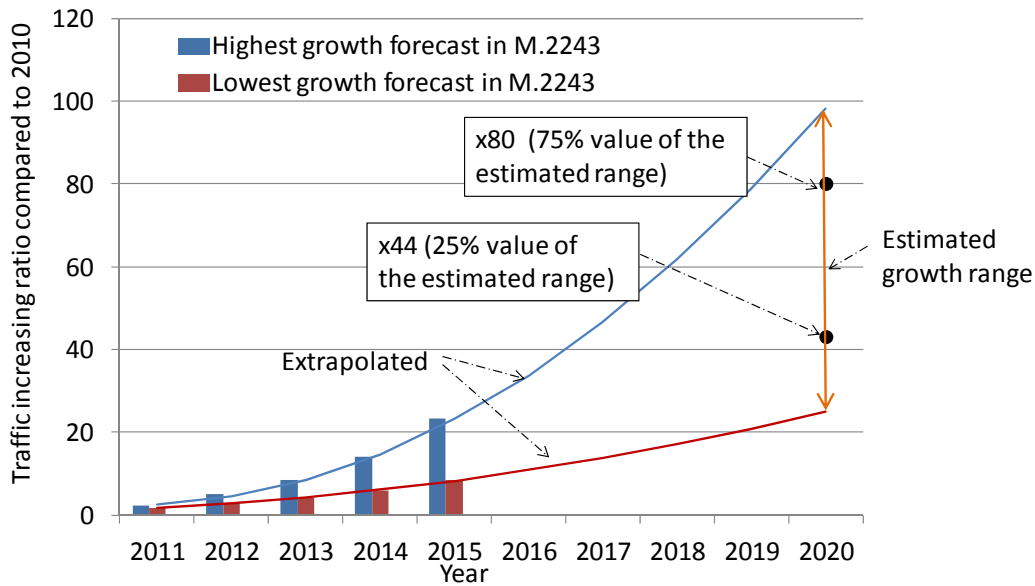
Based on the aggregate traffic volumes in 2010 from Report ITU-R M.2078, the new traffic volumes for the spectrum requirement estimations in 2020 are derived by considering traffic growth ratios from the market studies presented in Report ITU-R M.2243, where several mobile traffic forecasts beyond 2010 provided by different organizations are summarized (Fig. 8 of the Report). Most of these forecasts consider the mobile traffic in the years 2011-2015, while only one covers the year 2020, anticipating a 33-fold traffic growth ratio in 2020 compared to 2010. Therefore, in order to have a more reliable estimate in 2020, Fig. 5 below was prepared by extrapolating the traffic forecasts for the years 2011-2015 from Report ITU-R M.2243.

Two such forecasts, having the highest and lowest traffic growths, respectively, were selected and extrapolated towards 2020 by using the 2<sup>nd</sup>-order polynomial function ( $y = ax^2 + bx + c$ ). As indicated in Fig. 5, the estimated traffic in 2020 exhibits a 25 to 100-fold growth ratio compared to 2010. It should be noted that the above mentioned forecast anticipating a 33-fold traffic growth ratio falls into this estimated traffic growth range and another function ( $y = ax^r + b$ ) also provides similar extrapolation results up to 2020. Furthermore, it should be noted that the 2<sup>nd</sup>-order polynomial function estimates conservative traffic growth, while the 3<sup>rd</sup>- and 4<sup>th</sup>-order polynomial functions provide more aggressive growths corresponding to approximately 40 to 170-fold and 80 to 240-fold growth ratios, respectively<sup>3</sup>.

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<sup>3</sup> Details can be found in the Annex 3 – Mobile traffic forecasts towards 2020 by extrapolation.

FIGURE 5  
Mobile traffic forecasts toward 2020 by extrapolation



Based on the above Figure, two traffic growth ratios of 44- and 80-fold were used to define the market attributes for lower and higher user density settings in Tables A.1 and A.2 in Annex 1 to this Report, respectively. These ratios correspond to the 25% and the 75% values of the estimated growth range and are selected based on the following reasoning: for the year 2020, the median traffic growth will fall in between the lowest (red curve) and highest (blue curve) growths; adding 25% to the middle value of the estimated range yields the 80-fold increase, while subtracting 25% from the middle value of the estimated range yields the 44-fold increase. Note that the curves for other traffic growth estimates will fall in between these two curves (but are not shown in Fig. 1 for sake of clarity – rather they appear in Fig. C.1 in Annex 3), so the addition to/subtraction from the middle value of the estimated range of 25% is reasonable.

## 4.2 Service category parameters

### 4.2.1 Maximum allowable blocking probability for reservation-based service categories

The maximum allowable blocking probability parameter is used as a QoS indicator for reservation-based service categories. It is used in the calculation of the capacity requirement of the reservation-based SCs in Step 5 of the methodology in Fig. 3. Note that the concept of blocking also applies to reservation-based traffic management since, typically, an admission control function implies that newly arriving sessions might be blocked (otherwise the guaranteed QoS for existing sessions cannot be maintained/guaranteed).

The input values of the maximum allowable blocking probability for reservation-based service categories used in the spectrum requirements calculations are summarized in Table A.3 in Annex 1 to this Report.

### 4.2.2 Parameters for packet-switched service categories

The calculation of the capacity requirements of packet-switched SCs requires the following service category parameters:

- maximum allowable mean packet delay;
- mean packet size; and
- second moment of packet size.

The maximum allowable mean packet delay is the QoS indicator and describes the allowable delay for handling of the packets in the packet-switched SCs. The mean packet size and the second moment of the packet size describe the packet size distribution and are needed in the queuing theory model used for the capacity calculation.

The input values for the parameters for packet-switched service categories used in the spectrum requirements calculations are summarized in Tables A.4, A.5 and A.6 in Annex 1 to this Report.

It should be noted that the difference in the mean delay requirements per service category in Table A.6 from Report ITU-R M.2078 is related to the fact that mean delay requirements less than one millisecond are seen to be too low from a practical radio system point of view for IMT. Therefore, the mean delay requirements are updated compared to those given in Report ITU-R M.2078 as seen in Table A.6.

## 4.3 Radio-related parameters

The spectrum requirement estimation methodology in Recommendation ITU-R M.1768-1 uses radio-related input parameters that are defined in Report ITU-R M.2074. The radio parameters are used to model real-life wireless networks in a highly simplified fashion via the RATG approach (described in § 3.2). The radio parameters are interrelated and their values should be derived using the same framework including propagation conditions, interference situations, QoS criteria, and system characteristics. If one of the radio parameters is changed, others may also be influenced. For example, an improvement in the application data rates could be achieved with reduced cell area. Therefore, it is important to consider the parameter values jointly, if updates are required.

### 4.3.1 Cell area

The cell area parameter presents the area covered by macro cell, micro cell, pico cell and hot spot radio environments in different teledensities (examples being dense urban, suburban and rural). The cell area is independent of the RATGs but different in different teledensities. It is used in the calculation of the traffic in each cell (bit/s/cell) in Step 3 of the methodology flow chart in Fig. 3. The cell area parameter characterises a generalised situation for RATGs operating below 6 GHz as described in Report ITU-R M.2074. In the derivation of the cell areas, typical operational frequency ranges were considered for the different cell types.

The input values for cell area per radio environment used in the spectrum requirements calculations are summarized in Table A.7 in Annex 1.

### 4.3.2 Area spectral efficiency

The area spectral efficiency is expressed in bit/s/Hz/cell and describes how efficiently a RATG can use its available spectrum in terms of the data rate per bandwidth per cell. It is used to transform the capacity requirements into unadjusted spectrum requirements by dividing the capacity requirement per cell by the corresponding spectral efficiency. This corresponds to Step 6 of the methodology flow chart in Fig. 3.

The area spectral efficiency is calculated from the mean data throughput achieved over all users homogeneously distributed in the cell at the IP layer for packet-switched SCs and at the application layer for reservation-based SCs. The spectral efficiency is independent of the link direction.

The input values for the area spectral efficiency used in the spectrum requirements calculations are summarized in Tables A.12 and A.13 in Annex 1.

### 4.3.3 Other radio-related input parameters

**Application data rate** is used in the methodology in the distribution of traffic to radio environments and RATGs in Step 4 of the methodology flow chart in Fig. 3. The mean service bit rate requirement of each service category is compared to the application data rate of the RATG in the given radio environment to determine whether the given service category can be supported in the given radio environment of the given RATG.

**Supported mobility classes** are used in the traffic distribution part in Step 4 of the methodology flow chart in Fig. 3. They are used to split the traffic of each service category among the different available radio environments based on the mobility patterns of the service category and the capabilities of the radio environments. Small cells can only support lower mobility while larger cells can also support higher mobility.

**Minimum deployment per operator per radio environment** is used in the adjustment of the spectrum requirements in Step 7 of the methodology flow chart in Fig. 3. It describes the minimum amount of spectrum needed by an operator to build a practical network with given RATG technology for a given radio environment.

**Granularity of deployment per operator per radio environment** is used for increments of the spectrum requirements. The minimum deployment parameter is closely related to the application data rate parameter, as it needs to ensure that the given application data rate is supported in the given radio environment.

**Guard band between operators** is used in Step 8 of the methodology flow chart in Fig. 3 to take into account the excess bandwidth that needs to be left between the bands of two operators to avoid harmful interference. If the number of overlapping network deployments is equal to one, the guard band between operators does not influence the results.

**Number of overlapping network deployments** denotes the number of networks of the same RATG typically operated by different operators that do not share the spectrum. This parameter is used in the calculation of the adjusted spectrum requirements in Steps 7 and 8 of the methodology flow chart in Fig. 3. If the number of overlapping network deployments is equal to one, it does not influence the results. When there are multiple overlapping network deployments, the raw spectrum requirement is first divided among the different network deployments. Adjustments are then applied in the form of minimum deployment per operator per radio environment and guard bands between operators and the spectrum requirements are aggregated over the overlapping network deployments.

**Support for multicast** parameter denotes whether a given RATG can provide multicast transmission, i.e. transmit multicast traffic to multiple users simultaneously. It is used in Step 4 of the methodology flow chart in Fig. 3 in the traffic distribution where the distribution is done separately for unicast and multicast traffic.

The input values for these other radio input parameters used in the spectrum requirements calculations are summarized in Tables A.8, A.9, A.10 and A.11 in Annex 1.

## 4.4 Other parameters

### 4.4.1 Population coverage percentage

The population coverage percentage parameter is used in the traffic distribution part of the methodology where the traffic is distributed to different radio environments and RATGs in Step 4 of the methodology flow chart in Fig. 3. The population coverage percentage denotes the ratio of the population that is in the service area of a given radio environment in a given service environment. It puts a limit to the fraction of traffic that can be distributed to a given radio environment.

The input values for the population coverage percentage used in the spectrum requirements calculations are summarized in Table A.14 in Annex 1.

### 4.4.2 Distribution ratios among available RATGs

The distribution ratios among available RATGs are used to distribute traffic among different RATGs in Step 4 of the methodology flow chart in Fig. 3. This parameter influences the splitting of the traffic of a given service category between the different RATGs when multiple RATGs are available to support the service category in the given radio environment. This traffic distribution step in the methodology takes into account the mobile data offloading from IMT to RLAN, i.e. from RATG 1 and RATG 2 to RATG 3. As discussed there, it should be noted that a change in this parameter value does not necessarily result in a substantial change in the final adjusted spectrum requirement as it influences the splitting of the traffic of each service category. This parameter does not denote the overall splitting of the total traffic volume among the different RATGs but it is used to split the traffic of each service category separately in the case when there are multiple RATGs available in the given radio environment. There may be different radio environments and RATGs available for the different service categories depending on their capabilities and requirements and thus the influence of the change in this parameter value is not always directly visible.

The input values for the population coverage percentage used in the spectrum requirements calculations are summarized in Table A.15 in Annex 1.

## 5 Estimated spectrum requirements

The spectrum requirements are calculated for RATG 1 (i.e. pre-IMT, IMT-2000, and its enhancements) and RATG 2 (i.e. IMT-Advanced) for the year 2020. The spectrum requirements are calculated using the methodology defined in Recommendation ITU-R M.1768-1 and the input parameter values given in § 4 and the Annexes of this Report.

There are differences in the markets and deployments and timings of the mobile data growth in different countries.

Therefore, two settings are developed to characterise lower and higher user density settings as explained in § 4.1.3. These two sets of market study input parameter values are considered in the calculations to characterise differences in the user densities in different countries.

Table 1 shows the calculated spectrum requirements for both RATGs 1 and 2.

TABLE 1

**Total spectrum requirements for both RATG 1 and RATG 2 in the year 2020**

	<b>Total spectrum requirements for RATG 1</b>	<b>Total spectrum requirements for RATG 2</b>	<b>Total spectrum requirements RATGs 1 and 2</b>
Lower user density settings	440 MHz	900 MHz	1 340 MHz
Higher user density settings	540 MHz	1 420 MHz	1 960 MHz

In some countries, national spectrum requirement can be lower than the estimate derived by lower user density settings and in some other countries, national spectrum requirement can be higher than the estimate derived by higher user density settings.

## **6 Conclusions**

This Report provides results of studies on estimated spectrum requirements for terrestrial IMT. The estimated spectrum requirements are calculated using the methodology defined in Recommendation ITU-R M.1768-1 and the corresponding input parameter values, taking into account recent advances in technologies and the deployments of terrestrial IMT networks as well as recent developments in mobile telecommunication markets.

The total spectrum requirements for both RATG 1 (i.e. pre-IMT, IMT-2000, and its enhancements) and RATG 2 (i.e. IMT-Advanced) in the year 2020 are estimated using the two different settings in order to reflect differences in the markets and deployments and timings of the mobile data growth in different countries. The estimated total spectrum requirements for both the RATGs 1 and 2 are 1 340 MHz and 1 960 MHz for lower user density settings and higher user density settings, respectively.



## Annex 1

### Input parameter values used in the spectrum requirements calculation

#### A.1 Market-related input parameters

TABLE A.1

***J*-values for mapping of mobility classes in different service environments**

Service environment <i>m</i>	<i>J<sub>m</sub></i> -value
1	1
2	1
3	1
4	1
5	0.5
6	0

TABLE A.2

**(a) Market attributes in 2020 for lower user density settings<sup>4</sup>**

SC	U (%)	Q (%)	R (%)	μ(%)	Mobility ratio
1	25	40	40	40	2 (No range M.2072)
2	25	40	40	40	2
3	25	40	40	40	2
4	25	40	40	40	2
5	25	40	40	40	2
6	25	40	40	40	2 (No range M.2072)
7	25	40	40	40	2
8	25	40	40	40	2
9	25	40	40	40	2 (No range M.2072)
10	25	40	40	40	2
11	25	40	40	40	1
12	25	40	40	40	2
13	25	40	40	40	2
14	25	40	40	40	2
15	25	40	40	40	2
16	25	40	40	40	2 (No range M.2072)
17	25	40	40	40	2
18	25	40	40	40	2 (No range M.2072)
19	25	40	40	40	2 (No range M.2072)
20	25	40	40	40	2

<sup>4</sup> The exact values of the market attributes corresponding to the lower user density settings are shown in Table B.1 in Annex 2.

TABLE A.2 (*end*)**(b) Market attributes in 2020 for higher user density settings<sup>5</sup>**

SC	$U$ (%)	$Q$ (%)	$R$ (%)	$\mu$ (%)	Mobility ratio
1	46	40	40	40	2 (No range M.2072)
2	46	40	40	40	2
3	46	40	40	40	2
4	46	40	40	40	2
5	46	40	40	40	2
6	46	40	40	40	2 (No range M.2072)
7	46	40	40	40	2
8	46	40	40	40	2
9	46	40	40	40	2 (No range M.2072)
10	46	40	40	40	2
11	46	40	40	40	1
12	46	40	40	40	2
13	46	40	40	40	2
14	46	40	40	40	2
15	46	40	40	40	2
16	46	40	40	40	2 (No range M.2072)
17	46	40	40	40	2
18	46	40	40	40	2 (No range M.2072)
19	46	40	40	40	2 (No range M.2072)
20	46	40	40	40	2

**A.2 Service category parameters**

TABLE A.3

**Maximum allowable blocking probability for reservation-based service categories**

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

<sup>5</sup> The exact values of the market attributes corresponding to the higher user density settings are shown in Table B.2 in Annex 2.

TABLE A.4

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

<b>Traffic class</b> <b>Service type</b>	<b>Conversational</b>	<b>Streaming</b>	<b>Interactive</b>	<b>Background</b>
Super-high multimedia	Treated as reservation-based*	Treated as reservation-based*	3 292.23	3 054.00
High multimedia	Treated as reservation-based*	Treated as reservation-based*	1847.82	3 307.86
Medium multimedia	Treated as reservation-based*	Treated as reservation-based*	1 021.60	1 369.33
Low rate data and low multimedia	Treated as reservation-based*	Treated as reservation-based*	102.56	235.50
Very low rate data	Treated as reservation-based*	Treated as reservation-based*	47.61	235.50

\* Refers to circuit switched emulation.

TABLE A.5

**Second moment of the IP packet size per service category for the year 2020 (unit: byte<sup>2</sup>/packet<sup>2</sup>)**

<b>Traffic class</b> <b>Service type</b>	<b>Conversational</b>	<b>Streaming</b>	<b>Interactive</b>	<b>Background</b>
Super-high multimedia	Treated as reservation-based*	Treated as reservation-based*	27 552 481.16	20 332 660.50
High multimedia	Treated as reservation-based*	Treated as reservation-based*	15349865.20	27 691 445.33
Medium multimedia	Treated as reservation-based*	Treated as reservation-based*	6 592 429.07	11 523 733.33
Low rate data and low multimedia	Treated as reservation-based*	Treated as reservation-based*	138 595.74	1 827 768.50
Very low rate data	Treated as reservation-based*	Treated as reservation-based*	36 019.39	1 827 768.50

\* Refers to circuit switched emulation.

TABLE A.6

Mean delay requirements per service category for the year 2020 (unit: ms/packet)

<b>Traffic class</b> <b>Service type</b>	<b>Conversational</b>	<b>Streaming</b>	<b>Interactive</b>	<b>Background</b>
Super-high multimedia	Treated as reservation-based*	Treated as reservation-based*	20	20
High multimedia	Treated as reservation-based*	Treated as reservation-based*	20	20
Medium multimedia	Treated as reservation-based*	Treated as reservation-based*	20	20
Low rate data and low multimedia	Treated as reservation-based*	Treated as reservation-based*	20	20
Very low rate data	Treated as reservation-based*	Treated as reservation-based*	20	20

\* Refers to circuit switched emulation.

### A.3 Radio-related parameters

TABLE A.7

Assumed cell area per radio environment (km<sup>2</sup>) (with penetration loss)

<b>Radio environment</b>	<b>Teledensity</b>		
	<b>Dense urban</b>	<b>Suburban</b>	<b>Rural</b>
Macro cell	0.10	0.15	0.87
Micro cell	0.07	0.10	0.15
Pico cell	0.0016	0.0016	0.0016
Hot spot	0.000065	0.000065	0.000065

NOTE – Hot spots are geographically isolated from each other.

TABLE A.8

**Radio parameters for RATG 1**

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

TABLE A.9

**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
Granularity of deployment per operator per radio environment (MHz)	20	20	20	20
Number of overlapping network deployment	1			

TABLE A.10

**Radio parameters for RATG 3**

Parameters	Macro cell	Micro cell	Pico cell	Hot spot
Application data rate (Mbit/s)	–	–	50	500
Supported mobility classes	–	–	Stationary/ pedestrian	Stationary/ pedestrian
Support for multicast (yes=1, no=0)	Yes			

TABLE A.11

**Radio parameters for RATG 4**

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

TABLE A.12

**Area spectral efficiency for RATG 1 in 2020 (bit/s/Hz/cell)****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	4
Suburban	2	4	4	4
Rural	2	4	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	2
Suburban	1	2	2	2
Rural	1	2	2	2

TABLE A.13

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

Tele-density	Radio environments			
	Macro cell	Micro cell	Pico cell	Hot spot
Dense urban	4	5	5	7.3
Suburban	4	5	5	7.3
Rural	4	5	5	7.3

**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

NOTE – The spectrum efficiency values in Tables A.12 and A.13 are to be used only for spectrum requirement estimation by Recommendation ITU-R M.1768. These values are based on a full buffer traffic model in accordance with Report ITU-R M.2135. They are combined with the values of many other parameters within the Recommendation ITU-R M.1768 methodology to develop spectrum requirement estimate for IMT. In practice, such spectrum efficiency values are unlikely to be achieved due to the random nature of traffic, errors caused by radio channel conditions or packet losses. Furthermore, stochastic ‘file transfer’ simulation models show that actual spectral efficiency values are lower than the values shown in Tables A.12 and A.13 above, depending on inter-site distance.

## A.4 Other parameters

TABLE A.14

**Population coverage percentage (%) of the radio environments in each service environment in 2020**

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

TABLE A.15

**Distribution ratios among available RAT groups in 2020<sup>6</sup>**

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	50	40

<sup>6</sup> The Recommendation ITU-R M.1768-1 methodology did not include a specific parameter or model that would easily allow considerations of the influence of the offloading effect. Table 24c corresponds to cases where several RATGs are supported in the same radio environment for a given service category and indicates how the traffic is split in those circumstances.

In the case that RATGs 1, 2 and 3 are all available and if distribution ratio to RATG 3 decreases (while distribution ratio to RATG 2 increases), then traffic demands of RATG 2 in the Picocell and Hot spot would increase significantly. For example, when distribution ratio to RATG 3 decreases from 40% to 10% (less mobile offloading to RLAN) and RATG 2 distribution ratio would be 80% then traffic in Pico cell and Hot spot would increase by about 40-60 %. As a single input parameter, a change in the traffic distribution ratios when RATGs 1, 2 and 3 are available will not necessarily have an impact on overall spectrum requirements.

## Annex 2

**Real values of market attributes used in the spectrum requirements calculation**

TABLE B.1

(a) Market attribute in year 2020 for unicast downlink (lower user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	4 730.0	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	2	17 062.5	0.8	13 920.0	611.4	100.0	0.0	0.0	0.0
2	3	10 216.8	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	4	1 419.0	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	5	3 789.3	0.8	13 920.0	607.2	100.0	0.0	0.0	0.0
2	6	283.8	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
3	1	18 096.0	0.4	648.0	241.4	69.0	21.0	10.0	0.0
3	2	35 528.0	0.6	482.4	246.4	69.0	26.0	5.0	0.0
3	3	26 291.5	0.3	593.2	156.2	47.0	43.0	10.0	0.0
3	4	2 338.5	0.9	365.6	235.6	65.5	22.0	12.5	0.0
3	5	5 266.3	1.2	345.6	189.6	49.0	16.0	30.0	5.0
3	6	387.8	0.4	355.2	174.8	46.0	11.5	35.0	7.5
4	1	13 089.8	1.3	96.0	1 047.6	73.8	11.9	9.5	4.8
4	2	13 128.0	1.3	96.0	1 047.6	73.1	16.5	5.7	4.7
4	3	17 421.0	1.3	126.0	1 067.4	49.8	32.3	13.4	4.6
4	4	14.3	1.5	96.0	1 047.6	69.0	14.3	11.9	4.8
4	5	33.8	1.4	111.0	1 055.4	54.3	9.5	31.7	4.5
4	6	14.5	1.4	102.4	1 050.6	50.7	8.2	33.8	7.2
5	1	37 575.8	1.2	16.0	282.0	62.6	22.4	9.3	5.6
5	2	68 203.0	1.7	16.0	281.6	62.0	25.5	6.9	5.6
5	3	45 589.3	1.3	15.4	302.8	37.7	42.5	14.2	5.7
5	4	4 373.8	2.1	15.4	261.4	59.0	23.6	11.8	5.7



TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
5	5	8 709.5	2.8	12.4	306.8	34.1	23.4	36.6	5.9
5	6	842.8	2.1	15.4	260.8	36.1	18.3	36.1	9.6
6	1	1 743.0	0.0	418 000.0	150.0	55.0	25.0	20.0	0.0
6	2	1 743.0	0.0	418 000.0	150.0	55.0	35.0	10.0	0.0
6	3	2 324.0	0.0	418 000.0	150.0	10.0	70.0	20.0	0.0
6	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1	5 080.5	0.0	3 103.0	1 190.4	55.0	25.0	20.0	0.0
7	2	13 683.0	0.8	9 779.0	1 457.4	72.1	22.4	5.0	0.5
7	3	2 971.8	0.2	13 953.8	640.0	32.0	42.5	18.0	7.5
7	4	917.0	0.0	3 000.0	1 440.0	45.0	30.0	25.0	0.0
7	5	44.3	1.2	12 680.4	653.8	48.5	13.7	30.9	6.9
7	6	187.0	0.0	3 565.6	1 317.6	5.5	10.0	69.5	15.0
8	1	15 782.5	0.2	886.4	128.0	72.5	17.5	10.0	0.0
8	2	15 861.0	1.0	1 030.4	595.6	63.9	19.8	8.8	7.5
8	3	21 320.3	0.9	1 030.4	595.6	46.1	36.9	9.2	7.8
8	4	21.0	0.4	384.0	158.0	67.5	20.0	12.5	0.0
8	5	68.5	1.1	1 030.4	604.8	46.3	18.1	27.8	7.9
8	6	9.0	0.8	1 030.4	604.8	38.5	17.6	36.2	7.7
9	1	309.0	0.8	144.0	20.0	90.0	10.0	0.0	0.0
9	2	412.0	1.2	144.0	79.0	90.0	10.0	0.0	0.0
9	3	52.0	0.4	144.0	79.0	80.0	10.0	10.0	0.0
9	4	52.0	0.8	144.0	20.0	90.0	10.0	0.0	0.0
9	5	103.0	1.2	144.0	79.0	70.0	10.0	20.0	0.0
9	6	10.0	0.4	144.0	20.0	80.0	10.0	10.0	0.0
10	1	206.0	0.8	16.0	4.0	80.0	20.0	0.0	0.0
10	2	309.0	1.2	16.0	4.0	80.0	20.0	0.0	0.0
10	3	52.0	0.4	16.0	4.0	70.0	20.0	10.0	0.0
10	4	52.0	0.8	16.0	4.0	80.0	20.0	0.0	0.0
10	5	52.0	1.2	16.0	4.0	60.0	20.0	20.0	0.0
10	6	10.0	0.4	16.0	4.0	65.0	20.0	10.0	5.0
11	1	27.8	0.0	418 000.0	24.0	55.0	25.0	20.0	0.0
11	2	43.5	0.4	418 000.0	89.2	100.0	0.0	0.0	0.0

TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
11	3	18 793.8	0.4	90 209.6	8.0	10.0	70.0	20.0	0.0
11	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5	6 950.8	0.9	253 986.8	65.2	100.0	0.0	0.0	0.0
11	6	521.0	0.4	89 978.0	8.0	5.0	10.0	70.0	15.0
12	1	35 244.0	3.7	14 115.8	36.8	67.5	22.5	10.0	0.0
12	2	120 974.5	3.3	13 830.2	81.0	67.5	27.5	5.0	0.0
12	3	82 235.8	2.9	14 357.4	80.6	46.0	44.0	10.0	0.0
12	4	10 549.5	3.7	12 531.4	26.6	62.5	25.0	12.5	0.0
12	5	30 422.0	2.9	12 528.0	26.6	42.5	20.0	32.5	5.0
12	6	2 373.3	3.3	12 609.6	26.6	40.5	15.0	37.0	7.5
13	1	14 325.3	0.3	1 453.0	171.4	65.1	23.3	11.6	0.0
13	2	14 293.5	0.6	1 453.4	170.8	64.7	29.9	5.4	0.0
13	3	17 566.0	0.3	1 451.8	177.4	36.5	45.7	17.8	0.0
13	4	75.5	1.2	1 449.8	194.8	62.5	25.0	12.5	0.0
13	5	110.8	1.9	1 449.8	193.6	40.0	20.0	35.0	5.0
13	6	24.5	1.4	1 356.8	197.2	36.0	15.0	40.0	9.0
14	1	15 514.5	0.3	123.6	35.8	67.2	22.4	10.0	0.5
14	2	15 514.5	0.3	124.8	35.4	67.2	27.4	5.0	0.5
14	3	26 031.8	0.3	191.0	413.8	26.0	62.5	11.0	0.5
14	4	67.3	0.6	62.4	84.2	61.3	22.1	12.3	4.4
14	5	2 977.3	0.3	189.4	1 303.0	35.0	60.0	5.0	0.0
14	6	233.3	0.3	189.8	1 131.8	32.7	59.8	5.0	2.5
15	1	13 139.8	2.5	13.0	37.0	66.5	22.2	9.9	1.5
15	2	41 089.8	3.5	10.6	42.6	67.2	27.4	5.0	0.5
15	3	25 608.0	2.1	32.4	40.2	33.3	38.2	26.5	2.0
15	4	3 382.0	2.7	10.0	34.6	62.5	25.0	12.5	0.0
15	5	9 313.8	3.5	72.4	36.4	44.0	12.5	39.5	4.0
15	6	702.8	2.7	98.0	37.6	34.5	14.0	41.0	10.5
16	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2	52.0	0.8	20 000.0	222.0	80.0	20.0	0.0	0.0
16	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5	10.0	0.8	20 000.0	222.0	80.0	20.0	0.0	0.0

TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
16	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1	4 493.3	1.0	11 426.0	43.6	55.0	25.0	20.0	0.0
17	2	16 242.8	1.1	11 369.6	182.0	67.5	27.5	5.0	0.0
17	3	2 969.5	1.1	12 308.2	120.8	10.5	69.5	20.0	0.0
17	4	1 309.8	1.0	10 890.6	42.8	45.0	30.0	25.0	0.0
17	5	1 044.0	1.6	11 216.6	234.2	45.0	20.0	30.0	5.0
17	6	262.5	1.0	11 202.6	43.6	5.0	10.0	70.0	15.0
18	1	618.0	0.4	574.0	82.0	67.5	22.5	10.0	0.0
18	2	1 339.0	4.1	595.0	153.0	67.5	27.5	5.0	0.0
18	3	21.0	0.4	990.0	23.0	60.0	20.0	20.0	0.0
18	4	103.0	0.4	1 030.0	72.0	62.5	25.0	12.5	0.0
18	5	72.0	4.1	653.0	148.0	60.0	20.0	20.0	0.0
18	6	10.0	0.4	1 030.0	72.0	32.5	15.0	42.5	10.0
19	1	515.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	2	1 030.0	1.2	144.0	21.0	80.0	20.0	0.0	0.0
19	3	52.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
19	4	52.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	5	52.0	0.4	144.0	21.0	60.0	20.0	20.0	0.0
19	6	10.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
20	1	1 030.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	2	1 030.0	1.2	16.0	41.0	80.0	20.0	0.0	0.0
20	3	103.0	0.4	16.0	25.0	60.0	20.0	20.0	0.0
20	4	103.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	5	52.0	1.2	16.0	41.0	60.0	20.0	20.0	0.0
20	6	10.0	0.4	16.0	25.0	60.0	20.0	15.0	5.0

TABLE B.1 (continued)

## (b) Market attribute in year 2020 for unicast uplink (lower user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	52.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
2	2	57.0	1.2	20 000.0	265.0	100.0	0.0	0.0	0.0
2	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	21.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
2	5	10.0	1.2	20 000.0	35.0	100.0	0.0	0.0	0.0
2	6	1.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
3	1	18 389.3	0.4	635.2	269.8	69.0	21.0	10.0	0.0
3	2	35 875.3	0.6	407.2	254.8	69.5	25.5	5.0	0.0
3	3	26 338.0	0.3	494.8	201.0	46.5	43.5	10.0	0.0
3	4	2 415.8	0.9	345.6	256.8	66.0	21.5	12.5	0.0
3	5	5 309.0	1.2	345.6	221.6	49.0	16.0	30.0	5.0
3	6	389.3	0.4	345.6	194.0	46.0	11.5	35.0	7.5
4	1	13 089.8	1.3	96.0	4 010.0	73.8	11.9	9.5	4.8
4	2	13 128.0	1.3	96.0	4 010.0	73.1	16.5	5.7	4.7
4	3	17 421.0	1.3	2 614.4	4 029.8	49.8	32.3	13.4	4.6
4	4	14.3	1.5	96.0	4 010.0	69.0	14.3	11.9	4.8
4	5	33.8	1.4	1 266.0	4 017.8	54.3	9.5	31.7	4.5
4	6	14.5	1.4	609.2	4 013.0	50.7	8.2	33.8	7.2
5	1	37 575.8	1.2	16.0	282.0	62.6	22.4	9.3	5.6
5	2	68 203.0	1.7	16.0	281.6	62.0	25.5	6.9	5.6
5	3	45 589.3	1.3	15.4	302.8	37.7	42.5	14.2	5.7
5	4	4 373.8	2.1	15.4	261.4	59.0	23.6	11.8	5.7
5	5	8 709.5	2.8	12.4	306.8	34.1	23.4	36.6	5.9
5	6	842.8	2.1	15.4	260.8	36.1	18.3	36.1	9.6
6	1	1 743.0	0.0	401 966.2	150.0	55.0	25.0	20.0	0.0
6	2	1 743.0	0.0	401 966.2	150.0	55.0	35.0	10.0	0.0
6	3	2 324.0	0.0	401 966.2	150.0	10.0	70.0	20.0	0.0

TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
6	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1	11 366.8	0.2	3 205.0	467.2	55.0	25.0	20.0	0.0
7	2	35 845.3	1.2	9 914.0	518.0	65.9	20.7	7.4	6.0
7	3	23 151.5	0.3	3 861.0	478.4	32.0	42.5	18.0	7.5
7	4	2 802.8	0.3	3 195.2	470.4	0.0	0.0	0.0	0.0
7	5	7 518.3	1.3	9 914.6	514.8	48.5	13.7	30.9	6.9
7	6	564.3	0.3	3 258.6	470.8	28.5	12.0	44.0	15.5
8	1	15 782.5	0.2	845.6	66.6	72.5	17.5	10.0	0.0
8	2	15 861.0	1.0	1 030.4	524.2	70.0	21.7	6.3	1.9
8	3	21 320.3	0.9	1 030.4	524.2	48.3	38.6	9.7	3.4
8	4	21.0	0.4	384.0	39.0	67.5	20.0	12.5	0.0
8	5	68.5	1.1	1 030.4	533.4	50.0	15.0	30.0	5.0
8	6	9.0	0.8	1 030.4	533.4	42.5	10.0	40.0	7.5
9	1	309.0	0.8	144.0	30.0	90.0	10.0	0.0	0.0
9	2	412.0	1.2	144.0	118.0	90.0	10.0	0.0	0.0
9	3	52.0	0.4	144.0	118.0	80.0	10.0	10.0	0.0
9	4	52.0	0.8	144.0	30.0	90.0	10.0	0.0	0.0
9	5	103.0	1.2	144.0	118.0	70.0	10.0	20.0	0.0
9	6	10.0	0.4	144.0	30.0	80.0	10.0	10.0	0.0
10	1	2 934.5	0.9	12.4	1 445.4	67.5	22.5	10.0	0.0
10	2	10 239.8	1.1	12.4	1 445.4	67.5	27.5	5.0	0.0
10	3	6 043.8	0.6	12.4	1 445.4	40.0	45.0	15.0	0.0
10	4	873.0	0.9	12.4	1 445.4	62.5	25.0	12.5	0.0
10	5	2 263.0	1.1	12.4	1 445.4	35.0	20.0	40.0	5.0
10	6	174.3	0.6	12.4	1 445.4	35.0	15.0	40.0	10.0
11	1	27.8	0.0	403 932.4	24.0	55.0	25.0	20.0	0.0
11	2	43.5	0.4	403 932.4	33.0	100.0	0.0	0.0	0.0
11	3	37.0	0.0	403 932.4	24.0	10.0	70.0	20.0	0.0
11	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5	5.0	0.8	500 000.0	15.0	100.0	0.0	0.0	0.0
11	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1	22 068.5	0.4	12 209.6	22.6	68.3	22.1	9.0	0.5

TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
12	2	78 431.0	0.4	10 563.4	21.4	67.5	27.5	5.0	0.0
12	3	47 267.3	0.4	13 221.2	23.0	50.0	40.5	9.0	0.5
12	4	6 539.3	0.4	10 514.2	21.4	62.5	25.0	12.5	0.0
12	5	17 376.0	0.4	10 638.8	21.4	43.0	20.0	32.0	5.0
12	6	1 305.3	0.4	11 235.0	21.8	41.8	15.4	35.3	7.5
13	1	15 821.3	1.5	1 178.0	45.2	68.5	21.2	7.9	2.4
13	2	14 293.5	0.6	1 139.2	92.0	67.4	25.8	5.1	1.7
13	3	17 566.0	0.3	1 281.8	98.6	38.6	39.7	17.4	4.3
13	4	611.3	11.7	1 289.0	42.8	61.9	24.8	12.4	1.0
13	5	110.8	1.9	1 328.6	112.2	39.8	19.9	34.8	5.5
13	6	114.5	11.2	1 243.8	46.6	35.3	14.9	39.8	10.0
14	1	15 514.5	0.3	71.4	32.8	67.2	22.4	10.0	0.5
14	2	15 514.5	0.3	71.4	32.4	67.2	27.4	5.0	0.5
14	3	26 031.8	0.3	109.8	410.8	26.0	62.5	11.0	0.5
14	4	67.3	0.6	62.4	81.2	60.7	23.8	12.1	3.4
14	5	2 977.3	0.3	100.6	1 300.0	35.0	60.0	5.0	0.0
14	6	233.3	0.3	103.4	1 128.8	32.7	59.8	5.0	2.5
15	1	32 639.8	17.1	10.6	47.8	67.5	22.5	10.0	0.0
15	2	111 289.8	18.4	10.6	59.8	67.5	27.5	5.0	0.0
15	3	66 073.0	16.8	11.8	40.8	35.0	45.0	19.5	0.5
15	4	9 232.0	17.4	10.0	47.8	62.5	25.0	12.5	0.0
15	5	24 300.8	18.6	10.6	47.8	45.0	15.0	35.0	5.0
15	6	1 826.8	17.6	10.6	47.8	35.0	15.0	40.0	10.0
16	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2	52.0	0.8	20 000.0	25.0	80.0	20.0	0.0	0.0
16	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5	10.0	0.8	20 000.0	25.0	80.0	20.0	0.0	0.0
16	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1	316.3	0.7	15 915.0	124.8	56.6	24.2	19.2	0.0
17	2	737.0	1.5	14 336.4	160.6	67.5	27.5	5.0	0.0
17	3	548.3	0.9	18 062.6	155.2	13.9	66.2	19.4	0.5
17	4	56.5	1.0	12 778.4	121.2	45.3	29.9	24.9	0.0
17	5	147.3	1.6	12 602.0	151.8	45.0	20.0	30.0	5.0

TABLE B.1 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
17	6	12.0	1.0	14 737.0	133.2	7.0	10.0	68.0	15.0
18	1	618.0	0.4	574.0	35.0	80.0	20.0	0.0	0.0
18	2	1 339.0	4.1	595.0	66.0	80.0	20.0	0.0	0.0
18	3	21.0	0.4	990.0	10.0	60.0	20.0	20.0	0.0
18	4	103.0	0.4	1 030.0	31.0	80.0	20.0	0.0	0.0
18	5	72.0	4.1	653.0	63.0	60.0	20.0	20.0	0.0
18	6	10.0	0.4	1 030.0	31.0	60.0	20.0	15.0	5.0
19	1	515.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	2	1 030.0	1.2	144.0	21.0	80.0	20.0	0.0	0.0
19	3	52.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
19	4	52.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	5	52.0	0.4	144.0	21.0	60.0	20.0	20.0	0.0
19	6	10.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
20	1	1 030.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	2	1 030.0	1.2	16.0	41.0	80.0	20.0	0.0	0.0
20	3	1 211.3	0.6	13.6	10.6	35.0	45.0	20.0	0.0
20	4	103.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	5	459.0	1.1	13.6	17.0	35.0	20.0	40.0	5.0
20	6	39.0	0.6	13.6	10.6	32.5	15.0	42.5	10.0

## (c) Market attribute in year 2020 for multicast downlink (lower user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
2	1	51.5	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
2	2	10.3	1.7	20 000.0	5 554.5	100.0	0.0	0.0	0.0
2	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	20.6	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
2	5	3.1	1.7	20 000.0	2 468.7	100.0	0.0	0.0	0.0
2	6	1.0	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
3	1	391.4	1.7	1 424.2	1 130.4	83.0	17.0	0.0	0.0
3	2	463.5	2.5	922.7	1 587.0	84.0	16.0	0.0	0.0

TABLE B.1 (end)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
3	3	61.8	1.7	1 192.0	617.2	82.0	18.0	0.0	0.0
3	4	103.0	5.4	731.7	1 026.4	86.0	14.0	0.0	0.0
3	5	56.7	5.8	623.4	1 388.6	87.0	13.0	0.0	0.0
3	6	2.7	3.3	679.9	922.5	87.0	13.0	0.0	0.0

TABLE B.2

(a) Market attribute in year 2020 for unicast downlink (higher user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	8 703.2	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	2	31 356.4	0.8	13 920.0	611.4	100.0	0.0	0.0	0.0
2	3	18 798.8	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	4	2 611.0	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
2	5	6 966.3	0.8	13 920.0	607.2	100.0	0.0	0.0	0.0
2	6	522.1	0.2	13 920.0	480.0	0.0	0.0	0.0	0.0
3	1	30 683.4	0.4	648.0	241.4	69.0	21.0	10.0	0.0
3	2	61 434.4	0.6	482.4	246.4	69.0	26.0	5.0	0.0
3	3	48 255.4	0.3	593.2	156.2	47.0	43.0	10.0	0.0
3	4	3 783.7	0.9	365.6	235.6	65.5	22.0	12.5	0.0
3	5	9 391.7	1.2	345.6	189.6	49.0	16.0	30.0	5.0
3	6	699.2	0.4	355.2	174.8	46.0	11.5	35.0	7.5
4	1	24 041.5	1.3	96.0	1 047.6	73.8	11.9	9.5	4.8
4	2	24 069.0	1.3	96.0	1 047.6	73.1	16.5	5.7	4.7
4	3	32 037.0	1.3	126.0	1 067.4	49.8	32.3	13.4	4.6



TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
4	4	16.1	1.5	96.0	1 047.6	69.0	14.3	11.9	4.8
4	5	44.5	1.4	111.0	1 055.4	54.3	9.5	31.7	4.5
4	6	15.8	1.4	102.4	1 050.6	50.7	8.2	33.8	7.2
5	1	67 409.0	1.2	16.0	282.0	62.6	22.4	9.3	5.6
5	2	123 763.1	1.7	16.0	281.6	62.0	25.5	6.9	5.6
5	3	83 451.6	1.3	15.4	302.8	37.7	42.5	14.2	5.7
5	4	7 788.1	2.1	15.4	261.4	59.0	23.6	11.8	5.7
5	5	15 902.8	2.8	12.4	306.8	34.1	23.4	36.6	5.9
5	6	1 534.7	2.1	15.4	260.8	36.1	18.3	36.1	9.6
6	1	1 743.0	0.0	418 000.0	150.0	55.0	25.0	20.0	0.0
6	2	1 743.0	0.0	418 000.0	150.0	55.0	35.0	10.0	0.0
6	3	2 324.0	0.0	418 000.0	150.0	10.0	70.0	20.0	0.0
6	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1	9 348.1	0.0	3 103.0	1 190.4	55.0	25.0	20.0	0.0
7	2	25 003.7	0.8	9 779.0	1 457.4	72.1	22.4	5.0	0.5
7	3	5 468.0	0.2	13 953.8	640.0	32.0	42.5	18.0	7.5
7	4	1 687.3	0.0	3 000.0	1 440.0	45.0	30.0	25.0	0.0
7	5	55.4	1.2	12 680.4	653.8	48.5	13.7	30.9	6.9
7	6	344.1	0.0	3 565.6	1 317.6	5.5	10.0	69.5	15.0
8	1	28 996.1	0.2	886.4	128.0	72.5	17.5	10.0	0.0
8	2	29 097.7	1.0	1 030.4	595.6	63.9	19.8	8.8	7.5
8	3	39 220.9	0.9	1 030.4	595.6	46.1	36.9	9.2	7.8
8	4	21.0	0.4	384.0	158.0	67.5	20.0	12.5	0.0
8	5	82.4	1.1	1 030.4	604.8	46.3	18.1	27.8	7.9
8	6	12.4	0.8	1 030.4	604.8	38.5	17.6	36.2	7.7
9	1	309.0	0.8	144.0	20.0	90.0	10.0	0.0	0.0
9	2	412.0	1.2	144.0	79.0	90.0	10.0	0.0	0.0
9	3	52.0	0.4	144.0	79.0	80.0	10.0	10.0	0.0
9	4	52.0	0.8	144.0	20.0	90.0	10.0	0.0	0.0
9	5	103.0	1.2	144.0	79.0	70.0	10.0	20.0	0.0
9	6	10.0	0.4	144.0	20.0	80.0	10.0	10.0	0.0
10	1	206.0	0.8	16.0	4.0	80.0	20.0	0.0	0.0

TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
10	2	309.0	1.2	16.0	4.0	80.0	20.0	0.0	0.0
10	3	52.0	0.4	16.0	4.0	70.0	20.0	10.0	0.0
10	4	52.0	0.8	16.0	4.0	80.0	20.0	0.0	0.0
10	5	52.0	1.2	16.0	4.0	60.0	20.0	20.0	0.0
10	6	10.0	0.4	16.0	4.0	65.0	20.0	10.0	5.0
11	1	51.1	0.0	418 000.0	24.0	55.0	25.0	20.0	0.0
11	2	62.4	0.4	418 000.0	89.2	100.0	0.0	0.0	0.0
11	3	34 580.5	0.4	90 209.6	8.0	10.0	70.0	20.0	0.0
11	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5	12 785.2	0.9	253 986.8	65.2	100.0	0.0	0.0	0.0
11	6	958.6	0.4	89 978.0	8.0	5.0	10.0	70.0	15.0
12	1	64 675.9	3.7	14 115.8	36.8	67.5	22.5	10.0	0.0
12	2	222 333.5	3.3	13 830.2	81.0	67.5	27.5	5.0	0.0
12	3	151 305.4	2.9	14 357.4	80.6	46.0	44.0	10.0	0.0
12	4	19 367.4	3.7	12 531.4	21.2	62.5	25.0	12.5	0.0
12	5	55 932.8	2.9	12 528.0	21.2	42.5	20.0	32.5	5.0
12	6	4 362.6	3.3	12 609.6	21.2	40.5	15.0	37.0	7.5
13	1	24 628.1	0.3	1 453.0	149.3	65.1	23.3	11.6	0.0
13	2	24 569.6	0.6	1 453.4	148.6	64.7	29.9	5.4	0.0
13	3	32 234.9	0.3	1 451.8	156.3	36.5	45.7	17.8	0.0
13	4	112.0	1.2	1 449.8	176.6	62.5	25.0	12.5	0.0
13	5	117.3	1.9	1 449.8	175.2	40.0	20.0	35.0	5.0
13	6	24.9	1.4	1 356.8	177.9	36.0	15.0	40.0	9.0
14	1	25 951.1	0.3	123.6	30.6	67.2	22.4	10.0	0.5
14	2	25 951.1	0.3	124.8	30.3	67.2	27.4	5.0	0.5
14	3	47 725.4	0.3	191.0	314.1	26.0	62.5	11.0	0.5
14	4	106.1	0.6	62.4	66.9	61.3	22.1	12.3	4.4
14	5	5 391.6	0.3	189.4	981.0	35.0	60.0	5.0	0.0
14	6	416.6	0.3	189.8	852.6	32.7	59.8	5.0	2.5
15	1	21 581.5	2.5	13.0	37.0	66.5	22.2	9.9	1.5
15	2	73 009.5	3.5	10.6	42.6	67.2	27.4	5.0	0.5
15	3	46 945.7	2.1	32.4	40.2	33.3	38.2	26.5	2.0
15	4	6 049.8	2.7	10.0	34.6	62.5	25.0	12.5	0.0
15	5	17 050.8	3.5	72.4	36.4	44.0	12.5	39.5	4.0

TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
15	6	1 284.7	2.7	98.0	37.6	34.5	14.0	41.0	10.5
16	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2	52.0	0.8	20 000.0	222.0	80.0	20.0	0.0	0.0
16	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5	10.0	0.8	20 000.0	222.0	80.0	20.0	0.0	0.0
16	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1	8 267.6	1.0	11 426.0	43.6	55.0	25.0	20.0	0.0
17	2	29 843.0	1.1	11 369.6	182.0	67.5	27.5	5.0	0.0
17	3	5 463.9	1.1	12 308.2	120.8	10.5	69.5	20.0	0.0
17	4	2 409.9	1.0	10 890.6	42.8	45.0	30.0	25.0	0.0
17	5	1 912.6	1.6	11 216.6	234.2	45.0	20.0	30.0	5.0
17	6	483.0	1.0	11 202.6	43.6	5.0	10.0	70.0	15.0
18	1	618.0	0.4	574.0	82.0	67.5	22.5	10.0	0.0
18	2	1 339.0	4.1	595.0	153.0	67.5	27.5	5.0	0.0
18	3	21.0	0.4	990.0	23.0	60.0	20.0	20.0	0.0
18	4	103.0	0.4	1 030.0	72.0	62.5	25.0	12.5	0.0
18	5	72.0	4.1	653.0	148.0	60.0	20.0	20.0	0.0
18	6	10.0	0.4	1 030.0	72.0	32.5	15.0	42.5	10.0
19	1	515.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	2	1 030.0	1.2	144.0	21.0	80.0	20.0	0.0	0.0
19	3	52.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
19	4	52.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	5	52.0	0.4	144.0	21.0	60.0	20.0	20.0	0.0
19	6	10.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
20	1	1 030.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	2	1 030.0	1.2	16.0	41.0	80.0	20.0	0.0	0.0
20	3	103.0	0.4	16.0	25.0	60.0	20.0	20.0	0.0
20	4	103.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	5	52.0	1.2	16.0	41.0	60.0	20.0	20.0	0.0
20	6	10.0	0.4	16.0	25.0	60.0	20.0	15.0	5.0

TABLE B.2 (continued)

## (b) Market attribute in year 2020 for unicast uplink (higher user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	52.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
2	2	57.0	1.2	20 000.0	265.0	100.0	0.0	0.0	0.0
2	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	21.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
2	5	10.0	1.2	20 000.0	35.0	100.0	0.0	0.0	0.0
2	6	1.0	0.4	20 000.0	7 406.0	100.0	0.0	0.0	0.0
3	1	30 894.5	0.4	635.2	269.8	69.0	21.0	10.0	0.0
3	2	61 684.5	0.6	407.2	254.8	69.5	25.5	5.0	0.0
3	3	48 288.9	0.3	494.8	201.0	46.5	43.5	10.0	0.0
3	4	3 839.3	0.9	345.6	256.8	66.0	21.5	12.5	0.0
3	5	9 422.5	1.2	345.6	221.6	49.0	16.0	30.0	5.0
3	6	700.3	0.4	345.6	194.0	46.0	11.5	35.0	7.5
4	1	24 041.5	1.3	96.0	4 010.0	73.8	11.9	9.5	4.8
4	2	24 069.0	1.3	96.0	4 010.0	73.1	16.5	5.7	4.7
4	3	32 037.0	1.3	2 614.4	4 029.8	49.8	32.3	13.4	4.6
4	4	16.1	1.5	96.0	4 010.0	69.0	14.3	11.9	4.8
4	5	44.5	1.4	1 266.0	4 017.8	54.3	9.5	31.7	4.5
4	6	15.8	1.4	609.2	4 013.0	50.7	8.2	33.8	7.2
5	1	67 409.0	1.2	16.0	282.0	62.6	22.4	9.3	5.6
5	2	123 763.1	1.7	16.0	281.6	62.0	25.5	6.9	5.6
5	3	83 451.6	1.3	15.4	302.8	37.7	42.5	14.2	5.7
5	4	7 788.1	2.1	15.4	261.4	59.0	23.6	11.8	5.7
5	5	15 902.8	2.8	12.4	306.8	34.1	23.4	36.6	5.9
5	6	1 534.7	2.1	15.4	260.8	36.1	18.3	36.1	9.6
6	1	1 743.0	0.0	401 966.2	150.0	55.0	25.0	20.0	0.0
6	2	1 743.0	0.0	401 966.2	150.0	55.0	35.0	10.0	0.0
6	3	2 324.0	0.0	401 966.2	150.0	10.0	70.0	20.0	0.0

TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
6	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1	20 914.8	0.2	3 205.0	467.2	55.0	25.0	20.0	0.0
7	2	65 782.2	1.2	9 914.0	518.0	65.9	20.7	7.4	6.0
7	3	42 598.8	0.3	3 861.0	478.4	32.0	42.5	18.0	7.5
7	4	5 157.1	0.3	3 195.2	470.4	0.0	0.0	0.0	0.0
7	5	13 807.5	1.3	9 914.6	514.8	48.5	13.7	30.9	6.9
7	6	1 038.2	0.3	3 258.6	470.8	28.5	12.0	44.0	15.5
8	1	28 996.1	0.2	845.6	66.6	72.5	17.5	10.0	0.0
8	2	29 097.7	1.0	1 030.4	524.2	70.0	21.7	6.3	1.9
8	3	39 220.9	0.9	1 030.4	524.2	48.3	38.6	9.7	3.4
8	4	21.0	0.4	384.0	39.0	67.5	20.0	12.5	0.0
8	5	82.4	1.1	1 030.4	533.4	50.0	15.0	30.0	5.0
8	6	12.4	0.8	1 030.4	533.4	42.5	10.0	40.0	7.5
9	1	309.0	0.8	144.0	30.0	90.0	10.0	0.0	0.0
9	2	412.0	1.2	144.0	118.0	90.0	10.0	0.0	0.0
9	3	52.0	0.4	144.0	118.0	80.0	10.0	10.0	0.0
9	4	52.0	0.8	144.0	30.0	90.0	10.0	0.0	0.0
9	5	103.0	1.2	144.0	118.0	70.0	10.0	20.0	0.0
9	6	10.0	0.4	144.0	30.0	80.0	10.0	10.0	0.0
10	1	5 226.4	0.9	12.4	1 445.4	67.5	22.5	10.0	0.0
10	2	18 581.6	1.1	12.4	1 445.4	67.5	27.5	5.0	0.0
10	3	11 076.8	0.6	12.4	1 445.4	40.0	45.0	15.0	0.0
10	4	1 562.6	0.9	12.4	1 445.4	62.5	25.0	12.5	0.0
10	5	4 120.2	1.1	12.4	1 445.4	35.0	20.0	40.0	5.0
10	6	312.2	0.6	12.4	1 445.4	35.0	15.0	40.0	10.0
11	1	51.1	0.0	403 932.4	24.0	55.0	25.0	20.0	0.0
11	2	62.4	0.4	403 932.4	33.0	100.0	0.0	0.0	0.0
11	3	68.1	0.0	403 932.4	24.0	10.0	70.0	20.0	0.0
11	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5	5.0	0.8	500 000.0	15.0	100.0	0.0	0.0	0.0
11	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1	40 433.0	0.4	12 209.6	22.6	68.3	22.1	9.0	0.5

TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
12	2	144 053.5	0.4	10 563.4	21.4	67.5	27.5	5.0	0.0
12	3	86 963.3	0.4	13 221.2	23.0	50.0	40.5	9.0	0.5
12	4	11 988.5	0.4	10 514.2	21.4	62.5	25.0	12.5	0.0
12	5	31 928.2	0.4	10 638.8	21.4	43.0	20.0	32.0	5.0
12	6	2 397.5	0.4	11 235.0	21.8	41.8	15.4	35.3	7.5
13	1	27 380.7	1.5	1 178.0	45.2	68.5	21.2	7.9	2.4
13	2	24 569.6	0.6	1 139.2	92.0	67.4	25.8	5.1	1.7
13	3	32 234.9	0.3	1 281.8	98.6	38.6	39.7	17.4	4.3
13	4	951.7	11.7	1 289.0	42.8	61.9	24.8	12.4	1.0
13	5	117.3	1.9	1 328.6	112.2	39.8	19.9	34.8	5.5
13	6	190.5	11.2	1 243.8	46.6	35.3	14.9	39.8	10.0
14	1	25 951.1	0.3	71.4	32.8	67.2	22.4	10.0	0.5
14	2	25 951.1	0.3	71.4	32.4	67.2	27.4	5.0	0.5
14	3	47 725.4	0.3	109.8	410.8	26.0	62.5	11.0	0.5
14	4	106.1	0.6	62.4	81.2	60.7	23.8	12.1	3.4
14	5	5 391.6	0.3	100.6	1 300.0	35.0	60.0	5.0	0.0
14	6	416.6	0.3	103.4	1 128.8	32.7	59.8	5.0	2.5
15	1	57 461.5	17.1	10.6	47.8	67.5	22.5	10.0	0.0
15	2	202 177.5	18.4	10.6	59.8	67.5	27.5	5.0	0.0
15	3	121 401.3	16.8	11.8	40.8	35.0	45.0	19.5	0.5
15	4	16 813.8	17.4	10.0	47.8	62.5	25.0	12.5	0.0
15	5	44 626.9	18.6	10.6	47.8	45.0	15.0	35.0	5.0
15	6	3 352.8	17.6	10.6	47.8	35.0	15.0	40.0	10.0
16	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2	52.0	0.8	20 000.0	25.0	80.0	20.0	0.0	0.0
16	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5	10.0	0.8	20 000.0	25.0	80.0	20.0	0.0	0.0
16	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1	581.9	0.7	15 915.0	124.8	56.6	24.2	19.2	0.0
17	2	1 312.4	1.5	14 336.4	160.6	67.5	27.5	5.0	0.0
17	3	1 008.8	0.9	18 062.6	155.2	13.9	66.2	19.4	0.5
17	4	104.0	1.0	12 778.4	121.2	45.3	29.9	24.9	0.0
17	5	262.5	1.6	12 602.0	151.8	45.0	20.0	30.0	5.0

TABLE B.2 (continued)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
17	6	22.1	1.0	14 737.0	133.2	7.0	10.0	68.0	15.0
18	1	618.0	0.4	574.0	35.0	80.0	20.0	0.0	0.0
18	2	1 339.0	4.1	595.0	66.0	80.0	20.0	0.0	0.0
18	3	21.0	0.4	990.0	10.0	60.0	20.0	20.0	0.0
18	4	103.0	0.4	1 030.0	31.0	80.0	20.0	0.0	0.0
18	5	72.0	4.1	653.0	63.0	60.0	20.0	20.0	0.0
18	6	10.0	0.4	1 030.0	31.0	60.0	20.0	15.0	5.0
19	1	515.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	2	1 030.0	1.2	144.0	21.0	80.0	20.0	0.0	0.0
19	3	52.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
19	4	52.0	0.4	144.0	21.0	80.0	20.0	0.0	0.0
19	5	52.0	0.4	144.0	21.0	60.0	20.0	20.0	0.0
19	6	10.0	0.4	144.0	21.0	60.0	20.0	15.0	5.0
20	1	1 030.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	2	1 030.0	1.2	16.0	41.0	80.0	20.0	0.0	0.0
20	3	2 142.2	0.6	13.6	10.6	35.0	45.0	20.0	0.0
20	4	103.0	0.4	16.0	25.0	80.0	20.0	0.0	0.0
20	5	800.9	1.1	13.6	17.0	35.0	20.0	40.0	5.0
20	6	63.4	0.6	13.6	10.6	32.5	15.0	42.5	10.0

TABLE B.2 (end)

## (c) Market attribute in year 2020 for multicast downlink (higher user density settings)

SC	SE	User density (users/km <sup>2</sup> )	Session arrival rate per user (sessions/h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Mobility ratio			
						Stationary	Low	High	Super-high
2	1	51.5	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
2	2	10.3	1.7	20 000.0	5 554.5	100.0	0.0	0.0	0.0
2	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	20.6	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
2	5	3.1	1.7	20 000.0	2 468.7	100.0	0.0	0.0	0.0
2	6	1.0	0.4	20 000.0	14 812.0	100.0	0.0	0.0	0.0
3	1	391.4	1.7	1 424.2	1 130.4	83.0	17.0	0.0	0.0
3	2	463.5	2.5	922.7	1 587.0	84.0	16.0	0.0	0.0
3	3	61.8	1.7	1 192.0	617.2	82.0	18.0	0.0	0.0
3	4	103.0	5.4	731.7	1 026.4	86.0	14.0	0.0	0.0
3	5	56.7	5.8	623.4	1 388.6	87.0	13.0	0.0	0.0
3	6	2.7	3.3	679.9	922.5	87.0	13.0	0.0	0.0

## Annex 3

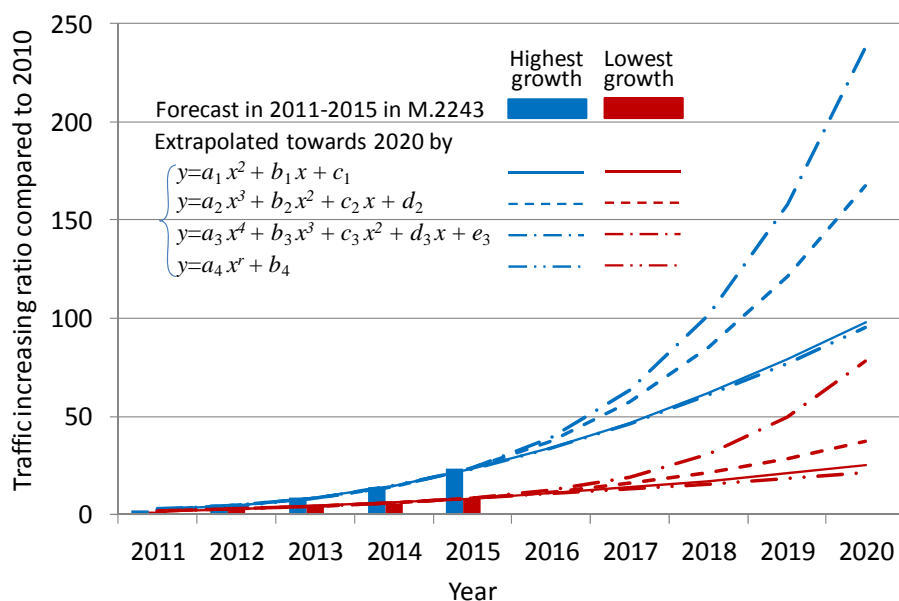
## Mobile traffic forecasts towards 2020 by extrapolation

Figure C.1 investigates mobile traffic forecasts towards 2020 by extrapolation of those in 2010-2015 that have the lowest and highest traffic growth, respectively, in Report ITU-R M.2243. The following different types of extrapolation functions are evaluated in the Figure:

- $y = a_1x^2 + b_1x + c_1$  (2<sup>nd</sup>-order polynomial);
- $y = a_2x^3 + b_2x^2 + c_2x + d_2$  (3<sup>rd</sup>-order polynomial);
- $y = a_3x^4 + b_3x^3 + c_3x^2 + d_3x + e_3$  (4<sup>th</sup>-order polynomial);
- $y = a_4x^r + b_4$ .



FIGURE C.1  
Mobile traffic forecasts towards 2020 by extrapolation



## Annex 4

### Summary of national spectrum requirements in some countries

The table below summarizes national spectrum requirements as provided by some member states and one sector member<sup>7</sup> at the time of approval of this Report. It should be noted that these national spectrum requirements have differences in the methodology used and assumptions made (e.g. differences in traffic/radio-aspects related parameters, differences in estimation year, differences in estimates based on whether the spectrum requirements are total or additional, etc.).

It should also be noted that the content of this Annex only covers case studies in some countries since member states were not requested to provide any information on national spectrum requirements during the development of this Report.

<sup>7</sup> The entry corresponding to the GSMA column is information received from GSMA concerning specific national spectrum requirements.

Source	US	Australia	Russia	China	GSMA6	India	UK
Estimation year	Until 2014	Until 2020	2020	2015, 2020	2020	2017, 2020	2020
Spectrum requirements	Additional requirement of 275 MHz by 2014	Total requirement of 1 081 MHz (Additional requirement of 300 MHz by 2020)	Total requirement of 1 065 MHz (Additional requirement of 385 MHz by 2020)	Total requirement of 570-690 MHz (by 2015) Total requirement of 1 490-1 810 MHz (by 2020)	Total requirement of 1 600-1 800 MHz for some countries	Additional requirement of 300 MHz by 2017 Additional requirement of another 200 MHz by 2020	Total requirement of 775-1 080 MHz for the low demand setting Total requirement of 2 230-2 770 MHz for the high demand setting
Methodology	Using an original methodology	Using an original methodology	Using an original methodology	Using the methodology in Rec. ITU-R M.1768-1	Using a new methodology to complement the methodology in Rec. ITU-R M.1768-1	Using an original methodology	Using the methodology in Rec. ITU-R M.1768-1

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