Questionnaire on the services and market for the future development of IMT-2000 and systems beyond IMT-2000

Subject: Questionnaire on the services and market for the future development of IMT-2000 and systems beyond IMT-2000

1   Introduction

Considering that the World Administrative Radio Conference 1992 and the World Radiocommunication Conference 2000 (WRC-2000) identified frequency bands for IMT-2000 (i.e., 806-960 MHz, 1 710-2 025 MHz, 2 110 2 200 MHz and 2 500-2 690 MHz), that the ITU Radiocommunication Assembly approved Question ITU-R 229/8 on the future development of IMT-2000 and systems beyond IMT-2000, and that WRC-03 approved Agenda Item 1.4 for WRC-07 and Resolution 228 (Rev.WRC-03) on "Studies on frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 as defined by ITU-R", ITU-R Working Party 8F (WP 8F) is studying, in preparation of WRC-07, the following aspects:

–   the mobile market and services expected to be used from around 2010 to 2020,

–   the methodology to estimate spectrum requirements,

–   the radio aspects of the future development of IMT-2000 and systems beyond IMT-2000,

–   the spectrum requirements estimated using the methodology developed, the forecast for the market and services and the radio aspects envisaged.

1   the spectrum requirements and possible candidate frequency bands to address these requirements.

All these studies will be used in the elaboration of the CPM (Conference Preparatory Meeting) text on WRC-07 Agenda item 1.4. In order to meet the CPM and WRC timelines, these studies are performed partly in parallel, but with synchronisation as the work progresses.

In the process of addressing the above mentioned Question, Recommendation ITU-R M.1645 on the framework of the future development of IMT-2000 and systems beyond IMT-2000 has already been produced. Additional Recommendations and Reports will be developed to address specific issues in more detail.

These specific issues will also include services provided by the future development of IMT-2000 and systems beyond IMT-2000. The ITU-R will deliver a Service/Market Analysis Report. This report will detail and summarize the results of studies on the potential future market aspects and services. The study results will assist activities to calculate the spectrum requirements for the future development of IMT-2000 and systems beyond IMT-2000.

2   Scope of this Questionnaire

Recommendation ITU-R M.1645 provides the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000. Following the framework in the Recommendation, the questionnaire lists survey questions to gather information on the analysis and forecast of services and market aspects from a range of organizations including organizations outside the ITU. The survey results will be used for the development of the Service/Market Analysis Report. The information provided in the Service/Market Analysis Report will be fed into the estimation of the spectrum requirements for future development of IMT-2000 and systems beyond IMT-2000 being developed in Recommendations on spectrum requirements calculation and on spectrum estimates.

3   Related documents

–   Recommendation ITU-R M. 1645, which can be obtained from
         http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=R-REC-M.1645.

4   Questions for services and market survey

The aim of this survey is to obtain comments from interested parties on a variety of issues relating to services and markets to be provided by and/or envisaged for the future development of IMT-2000 and systems beyond IMT-2000. The framework for these systems is described in Recommendation ITU-R M.1645. Results of this survey will be reflected in the Market/Service Analysis Report and other related activities within ITU-R.

The detailed survey questionnaire is attached electronically to this circular letter and is also available from the ITU web site at http://www.itu.int/ITU-R/study-groups/rsg8/rwp8f/index.asp under the heading "Research activities". We acknowledge that this questionnaire may not necessarily cover all aspects of the potential markets and services. The questions inquire about services provided by the future development of IMT-2000 and systems beyond IMT-2000 from 2010 to 2020. It is valuable to receive quantitative information from a range of organizations including organizations outside the ITU in answer to this questionnaire. If it is difficult to provide quantitative information at this stage, qualitative information would also be helpful for further activities in ITU-R WP 8F.

5   Schedule and contacts

–   Deadline for responses to the questionnaire to ITU-R WP 8F: end of December 2004.
–   If necessary, and after analysis of the received responses, additional information/questions for clarification will be produced by ITU-R WP 8F: end of February 2005.
–   Deadline for responses to the additional information/questions to ITU-R WP 8F: end of April 2005.

The schedule for other ITU-R WP 8F deliverables related to the future development of IMT-2000 and systems beyond IMT-2000 is shown in http://www.itu.int/ITU-R/study-groups/rsg8/rwp8f/index.asp

Administrations of Member States, Sector Members and ITU-R Associates participating in the work of Study Group 8 are encouraged to submit contributions in answer to this questionnaire. Moreover, they are invited to encourage research fora and external organizations to contribute to this activity: Answers to this Questionnaire may be contributed through ITU members or provided through a regional coordinator. More information, in particular on market aspects, if available, will be provided by the regional coordinators. A list of the ITU-R WP 8F appointed regional coordinators to assist the survey of future services and market is given below.

Region	Coordinator	E-mail
Africa	Mr. Denis NGAE (Cameroon)	denisngae@yahoo.fr
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Questionnaire on the services and market for the future development of IMT-2000 and systems beyond IMT-2000

Q1.   Services and market survey for existing mobile services

Regarding the 2G and 3G mobile communication services and market, including mobile satellite and wireless LAN services, please list information on the following parameters as they existed at the end of 2003.

1   Number of subscribers

2   Traffic volume

3   Expected time frame for transition from 2G to 3G

4   Regional and geographical characteristics

5   System type

6   Area covered

7   Commencement of operation

8   Economics of network deployment.

Q2.   Key market parameters

The market size of the future development of IMT-2000 and systems beyond IMT-2000 can be estimated from parameters such as density of potential users, call/session duration, service bandwidth and so forth. It is also necessary for the market size estimation to take account of key issues such as services usage and usage environments. Please list the key parameters and issues you consider necessary for the market size estimation, and comment on the impact of each parameter and issue on the market.

For example, the market study could provide the following parameters:

1   the number of mobile voice service subscribers;

2   the traffic volume for data service from mobile subscribers density of potential users in urban area during a specific time of day;

3   density of potential users in a rural/remote area for specific time of day;

4   average call duration of voice service during a specific time of day;

5   session activation rate of web browsing service by heavy users;

6   services and related Quality of Service parameters; guaranteed/best-effort, real time/non-real time, fixed/variable bit rate;

7   usage environments; high/low mobility, indoor/outdoor, business/private, urban/non-urban.

For these parameters the following reporting units could be used:

1 The number of service requests per unit time and area, i.e. session arrivals/s/m^2. The service request density is assumed to be identical in uplink and downlink direction. The value of this parameter could be provided for appropriate time intervals during the day, and separately for working days and non-working days, in order to account for non-simultaneously occurrence of the peak offered traffic of different service types.

2 Percentage of users in a set of mobility classes (stationary, pedestrian and vehicular)

3 Maximum required mobility support (km/h)

4 Mean service duration (s or amount of data)

5 Required minimum, average and maximum bit rate measured at the application layer (bit/s), for uplink and downlink

6 Required end-to-end delay (s).

Q3. Service and Market forecast for future development of IMT-2000 and systems beyond IMT-2000

Regarding services and markets of the future development of IMT-2000 and systems beyond IMT-2000, please provide forecasts on the future status of the parameters listed in Q2. Future trends of the parameters should be described in this question. When answering this question, please qualify the forecast. The evolution of service capabilities should also be described.

Q.3.1 Service issues

Please describe the applications envisaged for the future development of IMT-2000 and systems beyond IMT-2000, which may be pervasive from 2010 to 2020. Examples of potential future applications are shown in Annex 1.

Q.3.2 Market issues

Please describe the trends and scale of the market related to mobile communication from 2010 to 2020. Regarding the market scale, quantitative information is desirable. Please state how this information was obtained (e.g., methods and parameter values). An example of a method that can be used for market evolution forecast is given in Annex 3.

Q.3.3 Preliminary traffic forecast

Please provide information related to service traffic to be provided by the future development of IMT-2000 and systems beyond IMT-2000 from the year2010 to 2020(e.g. 2010, 2015 and 2020). The volume of traffic may be derived from information such as the number of service subscribers, service activation rate, service duration, transferred data size taking into account affordable expenses of the subscribers for this service. It may also be derived from information such as uplink and downlink speed, traffic class, service environment and economics of network deployment.

Examples of parameters that may be used to characterize the volume of traffic of these applications are shown in Annex 2. It is preferable that the information related to traffic volume be provided for each service listed in the answer to Q.3.1.

Q.3.4   Related information

Please provide any related information such as:

– impact of the number of operators;

– peak hour / peak ratio of traffic volume;

– expected affordable expenses in average per subscriber for the services; and

– economics of network deployment.

Q4.   Service and market forecast for other radio systems

The future development of IMT-2000 and systems beyond IMT-2000 are envisaged to interwork with other radio systems such as wireless LAN and broadcasting systems. Please list any radio systems that might interwork with the future development of IMT-2000 and systems beyond IMT-2000, and forecast the future status of the parameters from Q3. Please indicate the percentage of users that subscribe to multiple systems/operators.

Q5.   Driving forces of the future market

Please list any items which will be the driving forces in the markets of the future development of IMT-2000 and systems beyond IMT-2000, and estimate their impact and timing. There may be different drivers for different market areas, e.g., urban vs. rural/remote, in respective countries.

Q6.   Any other views on future services

If there are any other views on the services to be provided by the future development of IMT-2000 and systems beyond IMT-2000, which are not described in the Recommendation ITU-R M.1645, please express and elaborate on them.

Annex 1:   Examples of applications envisaged for the future development of IMT-2000 and systems beyond IMT-2000

Annex 2:   Examples of parameters for answers to Q.3.3

Annex 3:   An example of a method to forecast market evolution

Annex 1

Examples of applications envisaged for the future development of IMT-2000 and systems beyond IMT-2000

It is expected that there will be a large number of applications which will be provided by future development of IMT-2000 and systems beyond IMT-2000. The applications may be grouped into service categories. They could differ on a region or country basis.

The following table provides examples of potential future applications and their allocation to service categories and gives guidance to be used in the elaboration of answers to the Questionnaire. Respondents are encouraged to provide information according to this guidance.

Service categories	Examples of applications
Speech	•1 Voice
Multimedia messaging	•2 Mobile ordering enabling easy purchase of products or obtainment of information simply by holding a mobile terminal toward printed materials (magazines, brochures, posters, etc.) or images. Information pertaining to the product (video, CM, specifications) may be automatically delivered to the mobile terminal from the product centre, and displayed in 3D images, which can be viewed from multiple angles. Users, if they like, can order the product on the spot, make the payment and settle the accounts from a mobile terminal. Sales status in the areas nearby, and other related information on the product could also be obtained.
Low rate data	
Low multimedia	•3 Navigation System: users accessing information services from inside moving vehicles. The information should be provided adequately depending on time, location and properties of user. Users may also be able to receive discounts at shops by presenting the information retrieved through the above.
Medium multimedia	•4 Location information service (locating service, route guide, traffic information, etc.) •5 Vehicle information service (automobile information, vehicle tune-up information, etc).

	•6 Entertainment service (radio, TV programs, etc).
	•7 Control service (vehicle control in the event of earthquake, accident, etc).
	•8 Emergency service (accident, sudden illness, etc).
	•9 Logistics service (parcel delivery, etc).
	•10 Entertainment: Simply by instructing the name of video (which does not necessarily have to be precise; ambiguous input will do) of users' choice (TV programs broadcast in the past, news, dramas, movies, or concerts, etc.) through voice input, etc., users will be able to watch it on a mobile terminal through streaming from the network anytime and anywhere they like. The charges for the content—which should be decided taking into account the requests of the rights holder, the number of accesses from users (popularity), video quality, the number of copies, the time of viewing, location, etc.—will be presented on the spot, and if the user agrees, the video will be made available for viewing. Also, when the user wants to see a movie using some spare time, for instance, during a trip, he/she can search information concerning the movies currently on show and see a preview on the player. If he/she decides to watch the whole movie in a cinema, it is possible to search the theatre that can be reached from the current location before the start of the movie, and if necessary, make a seat reservation and purchase electronic tickets, too. The videos can be viewed in trains on a spectacles-type display, which can be suspended for a moment when changing trains.
High multimedia	
Very high multimedia	
Ultra high multimedia	
Super high multimedia	

Note that there is presently limited understanding as to the specific applications that will fit within the Very High, Ultra High or Super High categories. It is therefore proposed that these categories be reviewed once further information is available.

Annex 2

Examples of parameters for answers to Q.3.3

In order to establish spectrum requirements estimates, it is essential that the services envisaged are described in terms of technical characteristics. Therefore it is encouraged to establish a list of parameters and the values of these parameters for the various services. This annex lists examples of parameters that may be used to describe the characteristics of the various services.

A2.1 Traffic class

The different services can be divided into four traffic classes as follows:

– Constant Bit Rate (CBR) – CBR is a traffic class in which the peak bit rate takes a constant fixed value and is guaranteed. CBR is used for services that require a very low end-to-end delay as well as a low level of delay variation (jitter).

– Variable Bit Rate (VBR) – VBR class allows its bit rate to dynamically vary in response to the throughput actually required for the service. This class guarantees at least its sustainable bit rate and provides up to its peak bit rate if possible. The VBR has two subclasses according to its real-time nature; rtVBR (real-time VBR) and nrtVBR (non real-time VBR). In rtVBR, the peak bit rate is allowed to vary but real-time transmission is guaranteed, in which a tightly constrained delay and delay variations are required. The rtVBR is used for real-time applications, such as a voice and video communication. The nrtVBR is required to achieve a low packet loss ratio and mainly user for the applications of reliable and quick response like an electronic transaction. No delay bounds are defined in this category

– Available Bit Rate (ABR) – The ABR has no delay or delay variation requirements. This class is not intended for the use of real time applications. In this class, only peak bit rate and minimum usable bit rate are specified when establishing its connection. The minimum usable bit rate can be set to zero. The available bit rate may vary according to its network condition.

– Unspecified Bit Rate (UBR) – This class specifies no traffic related service guarantees. This class is intended for non-real-time applications, such as conventional computer communication applications; file transfer, or E-mail.

TABLE 1

Example mapping of potential applications on to Service types

Service Categories	CBR	VBR	ABR	UBR
Speech	Voice	–	VoIP	–
Multimedia messaging	–	–	High/Medium priority MMS	Low priority MMS
Low rate data	–	–	Organiser Sync Simple transactions	–
Low multimedia	–	–	Mobile commerce	–
Medium multimedia	Micro movies	Video telephony	Mobile commerce Location based advertising	
High multimedia	–	HD video telephony Video conferencing	Mobile commerce Down loads	
Very high multimedia	–	–	Desk top applications	
Ultra high multimedia	–	Streaming video Multiplayer gaming	Spooling video	
Super high multimedia	–	–	High volume applications	

A2.2 Bit rates

Bit rates are extremely important within the spectrum calculation and each service is likely to have different requirements. The peak bit rates are used here to categorize the services. For the purposes of modelling, however, it is possible to group together services demanding similar rates into a common category. To aid understanding of the hierarchy of categories, they are defined in terms of their peak user rate. This is distinct from the effective user rate which represents all services within the category for the purposes of spectrum calculation. Average bit rate may also be a parameter used to describe the characteristics of the service. For some services the delay may be relevant in addition to or instead of the peak bit rates.

A2.3 Degree of asymmetry

A driving parameter for categorisation is the degree of asymmetry for the Service. Precise asymmetries will vary between services, however, it is possible to group together services having similar asymmetry. The representative asymmetry for each group is subject to market assessment, but it is likely that there will be at least three variants to represent whether the service is fundamentally upload, download or symmetric. Download services are expected to use high bit rates on the down link and low

bit rates on the uplink or even no uplink data. Up load services use the reverse.

A2.4 Quality of service parameters

Quality of services parameters such as delay may be used to describe the characteristics of the various applications and services.

A2.5 Mobility

Terminal mobility is closely related to application usage scenarios. The requirements depend upon the relative speed between the mobile stations and the stations in the radio access network with which they are interacting. For example, the mobility may be categorized as follows:

– stationary (0 km/h);
– pedestrian (>0 and <10 km/h);
– vehicular (>10 km/h);
  – Low/Medium (>10 and <100 km/h)
  – High (>100 and <250 km/h)
  – Super-high (>250 km/h)

A2.6 Service usage patterns

A service usage pattern may be categorized according to an area where users exploit similar services and expect similar quality of service.

  – Home
  – Office
  – Public area
  – Wide area

The service usage pattern may be further categorized according to the time of day. The time-of-day variation of traffic volume depends on the type of application, which might have different usage such as:

  – busy time
  – non-busy time.

A2.7 Teledensity

Teledensity may be categorized into the following:

  – Dense Urban
  – Urban
  – Sub-urban
  – Rural
  – Remote

A2.8 Relations between the different parameters

Detailing all the combinations of parameters for each service would lead to very big amount of possibilities. Since not all these combinations reflect real cases, and in order to simplify the studies, a limited set of combinations of parameters may be used. The following tables provide some possible sets of combinations.

TABLE 2

Summary of service categories

Peak bit rate	Service categories
< 16 kbit/s	Speech
< 128 kbit/s	Multimedia messaging, Low multimedia, low rate data
< 384 kbit/s	Medium multimedia
< 2 Mbit/s	High multimedia
< 10 Mbit/s	Very high multimedia
< 30 Mbit/s	Ultra high multimedia
< 100 Mbit/s	Super high multimedia
Unspecified bit rate	Background

Note that there is presently limited understanding as to the specific applications that will fit within the Very High, Ultra High or Super High categories. It is therefore proposed that these categories be reviewed once further information is available. Similarly, it is premature to define the asymmetry associated with the up load and down load multimedia categories until further market data is available and the likely applications are better understood. Indeed it would be prudent to review all parameters associated with service categories in the light of market input before finalising the definition of each service category.

Table 3 describes the parameters that may be needed for the various traffic classes.

Note that all services which will be handled on a best effort basis are collected together under the service category Background. Thus the UBR traffic class is not required as a parameter in the definition of the other service categories.

TABLE 3

Additional parameters needed in addition to traffic class

| Traffic class	CBR	VBR	ABR	UBR
Information required	Quality of service Average bit rate Delay requirement	Quality of service Average bit rate Peak bit rate	Quality of service Average bit rate Minimum bit rate (or maximum delay)	None

Annex 3

An example of a method to forecast market evolution

Anticipating the evolution of the worldwide mobile communication penetration for the next twenty years is a challenging work. In this timeframe, as the world population increases by 22% (from 6,2 Billion in 2002 up to 7,6 Billion in 2020), many factors will influence the particular situation of each country and their telecommunication development. The forecasts for the evolution of telecommunication penetration developed from this method are based on the general socio-economic context and perspectives of each country.

For example, the penetration forecast could be set in two steps:

1   First, the long-term mobile penetration levels that the countries are expected to reach in 2020 are determined, as well as the maximum speed of penetration increase over the timeframe.

2   Second, the penetration evolution for every country, and for every year in the period 2003-2020 is computed using the so called S-Curve model.

An example of a particular method is presented in the figure below:
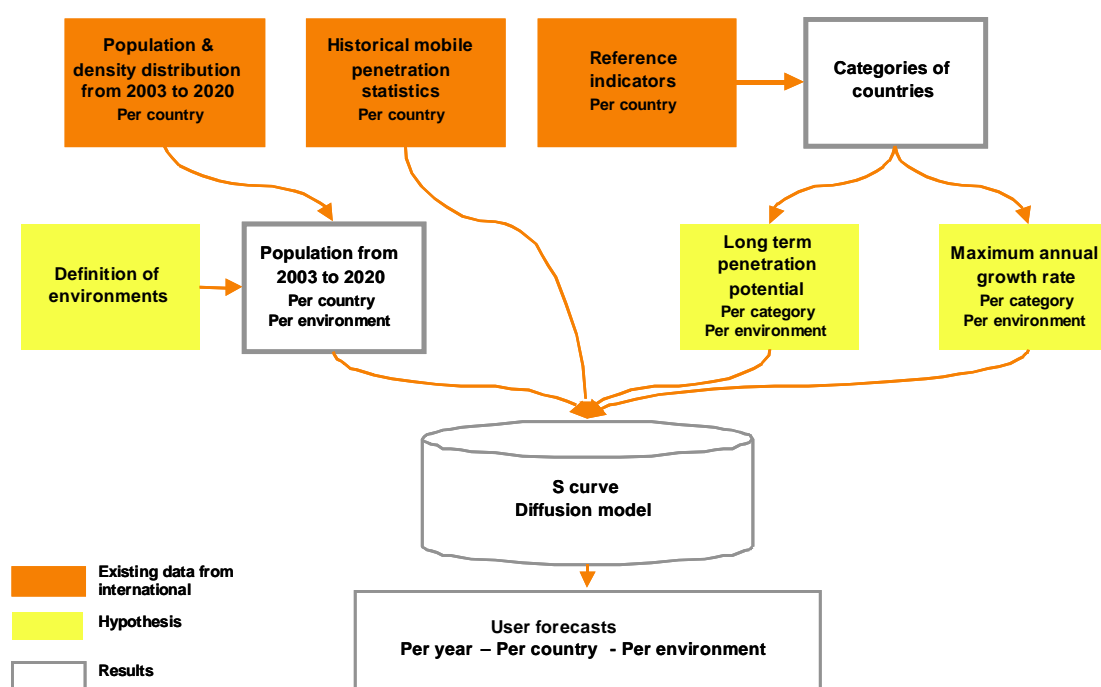
Synopsis of the mobile penetration forecast method

Four major reference indicators could be considered to estimate the future mobile telecommunication market in each country:

- ➢ Income
- ➢ Human Development
- ➢ Technology Affinity
- ➢ Urbanisation.

The evolution of the mobile penetration could be modelled per country and per environment as an S-curve diffusion process with the following parameters:

–   the historical mobile penetration in the country;

–   the long-term mobile penetration potential for the country;

–   the maximum year-on-year penetration growth rate (which occurs at the inflexion point of the penetration curve).

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Abbreviation	Organization
ABTO	Association of Basic Telecommunications Operators of India
AHCIET	Asociación Hispanoamericana de Centros de Investigación y Empresas de Telecomunicaciones
APT AWF	Asia Pacific Telecommunications Advanced Wireless Forum
ARIB	Association of Radio Industries and Businesses
ASETA	Asociacion de Empresas de Telecomunicaciones de la Comunidad Andina
ASMS-TF	Advanced Satellite Mobile Systems Task Force
ATIS	Alliance for Telecommunications Industry Solutions
ATRN	African Telecommunication Regulators Network
ATU	African Telecommunications Union
CANTO	Caribbean Association of National Telecommunication Organizations
CDG	CDMA Development Group
COAI	Cellular Operators Association of India
CEMAC	The Central African Economic and Monetary Community
CINSA	Community Information Network for Southern Africa
CITEL	Inter-American Telecommunication Commission
CEPT	European Conference of Postal and Telecommunications Administrations
COMESA	Common Market for Eastern and Southern Africa
Comtelca	Comision Tecnica Regional de Telecomunicaciones
CTIA	Cellular Telecommunications Internet Association
CWTA	Canadian Wireless Telecommunications Association
CCSA	China Communications Standard Association
DECT Forum	DECT Forum
DVB-Project	DVB Project Office
ECC PT1	ECC PT1 - UMTS/IMT-2000
ECOWAS	Economic Community of West African States
EICTA	European Information, Communications and Consumer Electronics Technology Industry Associations
ERO	European Radiocommunications Office
ETSI	European Telecommunications Standards Institute
EC	European Commission Information Society Directorate General
GSM Association	GSM Association
IEEE802	IEEE 802 LAN/MAN Standards Committee
Intellect	Information Technology Telecommunications and Electronics Association
IA 450	International 450 Association

Abbreviation	Organization
IPV6 Forum	IPV6 Forum
MITF	Mobile IT Forum
NGMC	Next Generation Mobile Communication Forum
OMA	Open Mobile Alliance
RASCOM	Regional African Satellite Communications Organisation
RCC	Regional Commonwealth in the Field of Communications
Regulatel	Foro Latinoamericano de Entes Reguladores de Telecomunicaciones
SADC	Southern African Development Community
TD-SCDMA Forum	TD-SCDMA Forum
TIA	Telecommunications Industry Association
TRASA	Telecommunications Regulators Association of Southern Africa
TTA	Telecommunications Technology Association
TTC	Telecommunications Technology Committee
UMTS Forum	UMTS Forum
UMTS TDD Alliance	UMTS TDD Alliance
WATRA	West Africa Telecommunications Regulators Association
WiFi Alliance	WiFi Alliance
WWRF	Wireless World Research Forum
3G Americas	3G Americas
3G Association	Third Generation Telecommunication Networks Operators Association (Russia)
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2

RECOMMENDATION ITU-R M.1645

Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

(Question ITU-R 229/8)

(2003)

1   Introduction

International Mobile Telecommunications-2000 (IMT-2000) systems are third generation mobile systems, which provide access to a wide range of telecommunication services, supported by the fixed telecommunication networks (e.g. PSTN/ISDN/IP), and to other services which are specific to mobile users.

Key features of IMT-2000 are:

–   high degree of commonality of design worldwide;

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

–   high quality;

–   small terminal suitable for worldwide use;

–   worldwide roaming capability;

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

The capabilities of IMT-2000 systems are being continuously enhanced in line with user demand and expectations and technology trends.

The specifications for the initial releases of IMT-2000, which are defined in Recommendation ITU-R M.1457, have been completed, and the commercial deployment of IMT-2000 has begun. Work is already under way in various external organizations to extend the capabilities of the initial releases in line with user expectations and technology trends.

To help meet the ever increasing demands for wireless communication, and the expected higher data rates needed to meet user demands, the ITU Radiocommunication Assembly approved Question ITU-R 229/8 on the future development of IMT-2000 and systems beyond IMT-2000. That Question asks generally about the overall objectives and the technical, operational and spectrum issues related to the future development of IMT-2000 and systems beyond IMT-2000. One of the initial steps in the process of addressing this Question is producing this Recommendation on the framework of the future development of IMT-2000 and systems beyond IMT-2000. Additional Recommendations and Reports will be developed to address specific issues in more detail.

2   Scope

This Recommendation defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network. This framework is based on the global user and technology trends, including the needs of developing countries. The Recommendation recommends the framework and objectives of the future development of IMT-2000 and systems beyond IMT-2000, specifically addressing:

–   evolutionary development of IMT-2000, which refers to the enhancements of its technical capabilities, range of available services and breadth of applications that will be progressively introduced during its lifetime;

–   systems beyond IMT-2000, for which there may be a need for a new wireless access technology to be developed around the year 2010, capable of supporting high data rates with high mobility, which could be widely deployed around the year 2015 in some countries.

The complete ITU framework for the future development of IMT-2000 and systems beyond IMT-2000 encompasses both the "radio access network" and the "core network". However, it is recognized that, in the future, the evolution of technologies and the redistribution of traditional functions between radio access networks and core networks in real systems may blur this distinction. The scope of this ITU-R Recommendation is the radio access network, while the core network is addressed in a companion ITU-T Recommendation ITU-T Q.1702. The framework for the future development of the IMT-2000 and systems beyond IMT-2000 radio access networks includes the emerging relationships with other radio access networks (existing and future), and the capabilities required to deliver services to the users of IMT-2000 and systems beyond IMT-2000.

3   Related Recommendations

ITU-R F.1399   Vocabulary of terms for wireless access

ITU-R M.687   International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.816   Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.818   Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.819   International Mobile Telecommunications-2000 (IMT-2000) for developing countries

ITU-R M.1034   Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.1035   Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.1182   Integration of terrestrial and satellite mobile communication systems

ITU-R M.1224   Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.1311   Framework for modularity and radio commonality within IMT-2000

ITU-R M.1450   Characteristics of broadband radio local area networks

ITU-R M.1457   Detailed specification of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

ITU-T Q.1702   Long-term Vision of Network Aspects for Systems Beyond IMT-2000

4   Considerations

The ITU Radiocommunication Assembly,

considering

4.1   User trends

In defining the framework for the future development of IMT-2000 and systems beyond IMT-2000, it is important to understand the user trends that will affect the development of such systems. In particular, the framework should be based on increasing user expectations and the growing demand for mobile services, as well as the evolving nature of the services and applications that may become available. The trends discussed below are thus an important underpinning of the framework.

4.1.1   Growing demand for mobile services

The number of mobile subscribers worldwide has increased from 215 million in 1997 to 946 million (15.5% of global population) in 2001 as shown in Fig. 1[1]. It is predicted that by the year 2010 there will be 1 700 million terrestrial mobile subscribers worldwide. A substantial portion of these additional subscribers are expected to be from outside the countries that already had substantial numbers of mobile users by the year 2001.

It is envisaged that, by the year 2020, potentially the whole population of the world could have access to advanced mobile communications devices, subject to, amongst other considerations, favourable cost structures being achieved. There are already more portable handsets than either fixed line telephones or fixed line equipment such as PCs that can access the Internet, and the number of mobile devices is expected to continue to grow more rapidly than fixed line devices. Mobile terminals will be the most commonly used devices for accessing and exchanging information.

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[1]   www.itu.int/ITU-D/ict/statistics.

FIGURE 1

Global growth of mobile and wireline subscribers
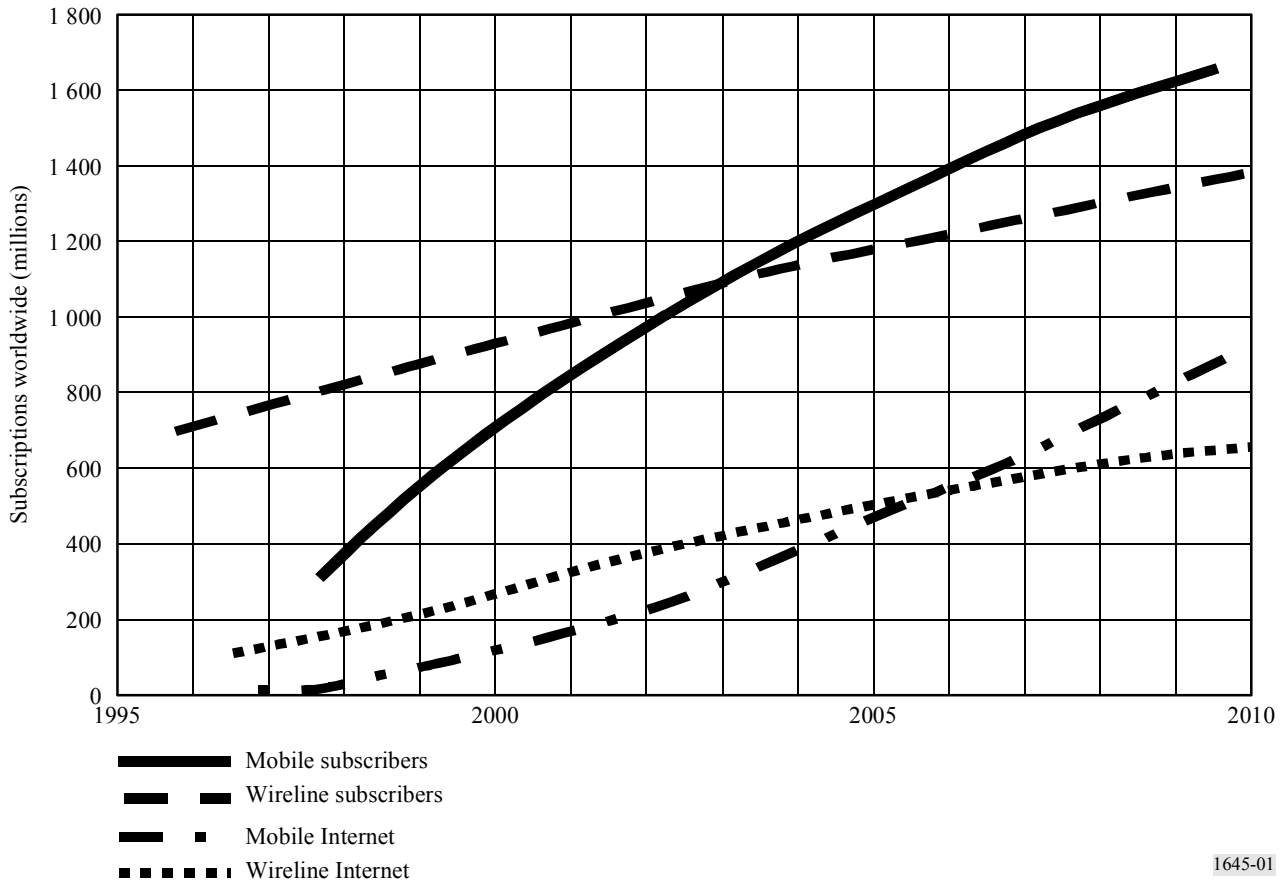
4.1.2   Trends in services and applications

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

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

External market studies have predicted that in Europe in the year 2010 more than 90 million mobile subscribers will use mobile multimedia services, generating about 60% of the traffic in terms of transmitted bits.

In Japan, mobile web browsing, which is one type of mobile multimedia service, started to become popular around the year 2000; the number of users was 48.5 million (72% of mobile subscribers) at the end of the year 2001 and is still growing.

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

–   connectivity (provision of a pipe, including intelligence in the network and the terminal);

–   content (information, including push and pull services);

–   commerce (transactions).

These trends may be viewed as the integration and convergence of information technology, telecommunications, and content. This will result in new service delivery dynamics and a new paradigm in telecommunications where value added services, such as those which are location dependent, will provide enormous benefits to both the end users and the service providers.
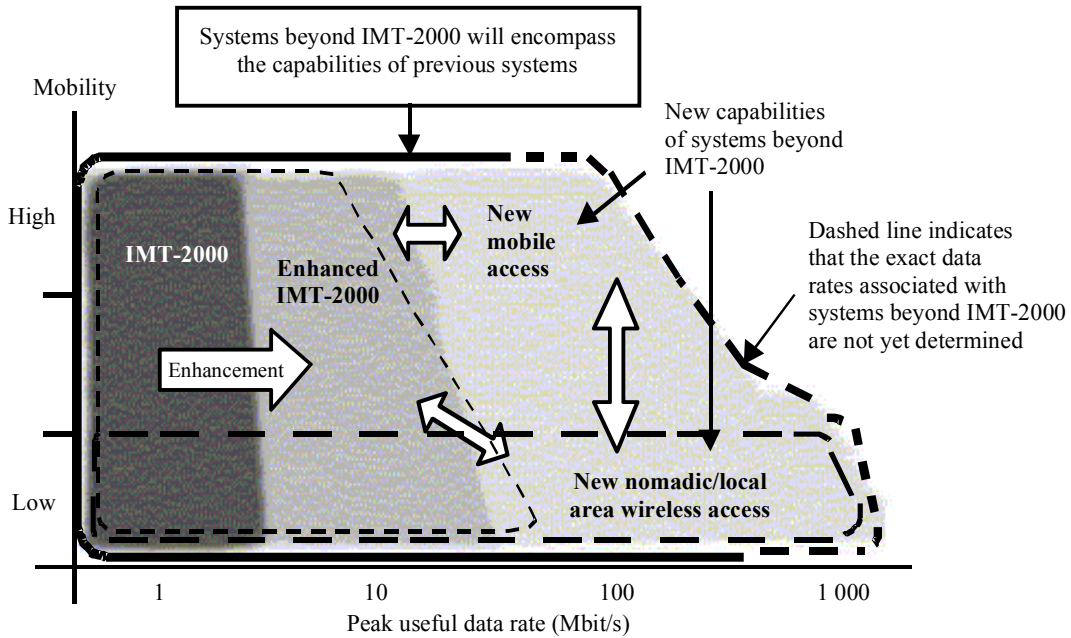
In addition, these trends are supported by "digitalization", which is already well advanced. The majority of electronic and communications devices and delivery mechanisms (i.e. cellular, broadcast, fixed wireless access (FWA), radio local area networks (RLANs), xDSL (digital subscriber line delivery mechanisms), satellite, etc.) are either already digital or in the process of migrating to digital technologies.

4.2   Framework

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

The framework for the future development of IMT-2000 and systems beyond IMT-2000 is depicted in Fig. 2, which illustrates the various components described in § 4.2.1 and their relationships to each other. Systems beyond IMT-2000 will encompass the capabilities of previous systems. Other communication relationships will also emerge, in addition to person to person, such as machine-to-machine, machine-to-person and person-to-machine.

FIGURE 2

Illustration of capabilities of IMT-2000 and systems beyond IMT-2000

Systems beyond IMT-2000 will encompass the capabilities of previous systems

New capabilities of systems beyond IMT-2000

Dashed line indicates that the exact data rates associated with systems beyond IMT-2000 are not yet determined

Mobility

High

Low

IMT-2000

Enhanced IMT-2000

Enhancement

New mobile access

New nomadic/local area wireless access

1   10   100   1 000

Peak useful data rate (Mbit/s)

Denotes interconnection between systems via networks, which allows flexible use in any environment without making users aware of constituent systems

Nomadic/local area access systems

Digital broadcast systems

Dark shading indicates existing capabilities, medium shading indicates enhancements to IMT-2000, and the lighter shading indicates new capabilities of systems beyond IMT-2000.

The degree of mobility as used in this Figure is described as follows: low mobility covers pedestrian speed, and high mobility covers high speed on highways or fast trains (60 km/h to ~250 km/h, or more).

1645-02

4.2.1   Objectives

The objectives of the future development of IMT-2000 and systems beyond IMT-2000 is considered to be as follows:

–   *Future development of IMT-2000:*

There will be a steady and continuous evolution of IMT-2000 to support new applications, products and services. For example, the capabilities of some of the IMT-2000 terrestrial radio interfaces are already being extended up to 10 Mbit/s and it is anticipated that these will be extended even further up to approximately 30 Mbit/s by around the year 2005, under optimum signal and traffic conditions. This is discussed in more detail in § 4.2.4.

–   *New capabilities of systems beyond IMT-2000:*

For systems beyond IMT-2000, there may be a requirement for a new wireless access technology for the terrestrial component, around the year 2010. This will complement the enhanced IMT-2000 systems and the other radio systems. It is predicted that potential new radio interface(s) will need to support data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, by around the year 2010. This is discussed in more detail in § 4.2.5.

These data rate figures and the relationship to the degree of mobility (Fig. 2) should be seen as targets for research and investigation of the basic technologies necessary to implement the framework. Future system specifications and designs will be based on the results of the research and investigations. Due to the predicted data rate requirements, additional spectrum will be needed in order to deliver the new capabilities of systems beyond IMT-2000. The data rate figures anticipate the advances in technology, and these values are expected to be technologically feasible in the time-frame noted above. It is possible that upstream and downstream may have different maximum transmission speeds.

–   *Relationship of IMT-2000, systems beyond IMT-2000, and other access systems:*

In conjunction with the future development of IMT-2000 and systems beyond IMT-2000, relationships will continue to develop between different radio access and communications systems, for example wireless personal area networks (WPANs), LANs (WLANs), digital broadcast, and FWA. This is discussed in more detail in § 4.2.6.

4.2.2   Perspectives on the objectives

The framework for the future development of IMT-2000 and systems beyond IMT-2000 can be considered from multiple perspectives, including the users, manufacturers, application developers, network operators, and service and content providers. From the user's perspective, there will be a demand for a variety of services, content and applications whose capabilities will increase over time. Similarly, users will expect services to be ubiquitously available through a variety of delivery mechanisms and service providers, using a wide variety of devices that will be developed to meet their differing requirements. These may resemble today's devices such as desktop and laptop PCs, mobile phones, digital televisions, and other computing and communication devices. User demands will be addressed by a large community including content providers, service providers, network operators, manufacturers, application and hardware developers.

The objectives, as seen from various perspectives can be summarized as in Table 1:

TABLE 1

Objectives from multiple perspectives

Perspective	Objectives
END USER	Ubiquitous mobile access
	Easy access to applications and services
	Appropriate quality at reasonable cost
	Easily understandable user interface
	Long equipment and battery life
	Large choice of terminals
	Enhanced service capabilities
	User-friendly billing capabilities
CONTENT PROVIDER	Flexible billing capabilities
	Ability to adapt content to user requirements depending on terminal, location and user preferences
	Access to a very large marketplace through a high similarity of application programming interfaces
SERVICE PROVIDER	Fast, open service creation, validation and provisioning
	Quality of service (QoS) and security management
	Automatic service adaptation as a function of available data rate and type of terminal
	Flexible billing capabilities
NETWORK OPERATOR	Optimization of resources (spectrum and equipment)
	QoS and security management
	Ability to provide differentiated services
	Flexible network configuration
	Reduced cost of terminals and network equipment based on global economies of scale
	Smooth transition from IMT-2000 to systems beyond IMT-2000
	Maximization of sharing capabilities between IMT-2000 and systems beyond IMT-2000 (sharing of mobile, UMTS subscriber identity module (USIM), network elements, radio sites)
	Single authentication (independent of the access network)
	Flexible billing capabilities
	Access type selection optimizing service delivery
MANUFACTURER/ APPLICATION DEVELOPER	Reduced cost of terminals and network equipment based on global economies of scale
	Access to a global marketplace
	Open physical and logical interfaces between modular and integrated subsystems
	Programmable platforms that enable fast and low-cost development

4.2.3   Coverage objectives

An objective of IMT-2000, defined in Recommendation ITU-R M.687, is to make a wide range of telecommunication services available to mobile users, and to provide these services over a wide range of teledensities (number of users per square kilometre) and geographic coverage areas. This continues to be a priority for the future development of IMT-2000 and systems beyond IMT-2000. Geographic coverage is especially important to developing countries because many people who do not at present have access to mobile communications live in parts of the world where the population density, teledensity, and/or income levels are low.

Satellite networks can provide services to wide areas in sparsely populated regions, such as rural and desert zones, maritime and aeronautical environments. From this point of view, satellite networks may provide a useful complement to the terrestrial networks.

Global economies of scale will help to lower entry costs, and thus help to bring telecommunications to people who do not presently have mobile or fixed line telephones. To achieve this goal, limited system complexity is beneficial.

Geographical coverage could be increased for the terrestrial component by also using lower frequency ranges than those today identified for IMT-2000, or by using the satellite component of IMT-2000, subject to market conditions and certain limitations, such as handset size, power consumption and indoor coverage. IMT-2000 services can best be provided at low cost to rural areas and to low-income populations by using globally harmonized frequencies to minimize terminal complexity and maximize economies of scale in order to minimize system cost.

To meet users' expectations, it is important that the service area of IMT-2000 networks is maintained for systems beyond IMT-2000 where needed, taking into account the effects of higher bit rate, operating frequency and advances in technology.

4.2.4   Future development of IMT-2000

The capabilities of IMT-2000 will continue to steadily evolve over at least the next ten years as IMT-2000 technologies are upgraded and deployed. From a radio access perspective, it is expected that the future development of IMT-2000 will build on and further develop the radio access systems and technologies already being developed and deployed. This would be followed by further operation for possibly a further ten years or more. This evolution will enhance stability and promote the development of an expanding number of services and applications.

Similarity of services and applications across the different IMT-2000 technologies and frequency bands is beneficial to users, and a broadly similar user experience leads to a large-scale take-up of products and services, common applications and content, and an ease and efficiency of use.

Terrestrial IMT-2000 systems are already being enhanced (for instance, towards IP-based network and to offer bit rates up to 10 Mbit/s under favourable circumstances). 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

circumstances by around 2005; however, some operators may need additional spectrum to realize these enhancements.

The satellite component of IMT-2000 may further evolve to provide complementary services (e.g. broadcasting, multicasting).

Today mobile-satellite services are mainly used in areas where there is no terrestrial mobile network. The future development of the satellite component of IMT-2000 is envisaged to complement future IMT-2000 networks, and is intended to provide higher data rates and new services (compared to today's satellite systems), in particular to individuals or devices that are outside the coverage of the terrestrial network.

4.2.5 New capabilities for systems beyond IMT-2000

The services that users will want, and the rising number of users, will place increasing demands on access networks. These demands may eventually not be met by the enhancement of IMT-2000 radio access systems (in terms of peak bit rate to a user, aggregate throughput, and greater flexibility to support many different types of service simultaneously). It is therefore anticipated that there will be a requirement for a new radio access technology or technologies at some point in the future to satisfy the anticipated demands for higher bandwidth services.

This Recommendation provides a very high-level view of the framework for the new capabilities envisaged for systems beyond IMT-2000, and the new radio interface(s) that might be needed to support them. Further ITU-R Recommendations will develop these concepts in more detail. Other new Recommendations will address spectrum requirements for systems beyond IMT-2000, which frequency bands might be suitable, and in what time-frame such spectrum would be needed, with a view to accommodating emerging broadband services and applications. It is expected that new spectrum requirements documented in these Recommendations will be addressed at a future World Radiocommunication Conference. This topic is included in Resolution 802 (WRC-03) as agenda item 1.4 for WRC-07.

Systems beyond IMT-2000 will support a wide range of symmetrical, asymmetrical, and unidirectional services. They will also provide management of different quality of service levels to realize the underlying objective of efficient transport of packet-based services. In parallel, there will be an increased penetration of nomadic and mobile wireless access multimedia services.

The technologies, applications and services associated with systems beyond IMT-2000 could well be radically different from the present, challenging the perceptions of what may be considered viable by today's standards and going beyond what can be achieved by the future enhancement of IMT-2000 working with other radio systems.

The new radio access interface(s) are 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 for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access (Fig. 2). These data rates are targets for research and investigation. They should not be taken as the definitive requirements for systems beyond IMT-2000.

These data rates will be shared between active users. The achievable (peak or sustained) throughput for any individual user depends on many parameters, including the number of active users, traffic characteristics, service parameters, deployment scenarios, spectrum availability, and propagation and interference conditions. These data rates are the maximum value of the sum of the data rate for all of the active users on a radio resource; it is possible that the peak data rate needed in the upstream direction will be different from the downstream direction. The transport data rates may need to be higher due to overheads, such as signalling and coding. Depending on the services for which the technology(ies) will be used, continuous radio coverage may not be needed in order to meet the service requirements.

4.2.6   Relationship of IMT-2000, systems beyond IMT-2000 and other access systems

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

–   content and services offered;

–   frequency bands of operation;

–   standards defining the systems;

–   data rates supported;

–   bidirectional and unidirectional delivery mechanisms;

–   degree of mobility;

–   regulatory requirements;

–   cost.

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

A similarity of services and applications across the different systems is beneficial to users, and this has stimulated the current trend towards convergence. Furthermore, a broadly similar user experience across the different systems leads to a large-scale take-up of products and services, common applications and content and an ease and efficiency of use. However, such convergence should not preclude opportunities for competitive innovation. Access to a service or an application may be performed using one system or may be performed using multiple systems simultaneously (e.g. a digital broadcast channel and a return channel using IMT-2000).

The increasing prevalence of IP-based applications is a key driver for this convergence and facilitates the establishment of relationships between previously separate wireless platforms. What form these relationships will take depends on user requirements, but they might include, for example, hardware integration within a device, network interworking, common access,

authentication, accounting, common man-machine interfaces, portals, roaming and handover between systems.

An individual person, or machine, might from time to time be a user on one or more of these systems, either sequentially or simultaneously, depending on the task at hand.

The formation of these relationships is distinct from the development of each wireless access system, including IMT-2000; it will need to take into account the characteristics and future development of the systems, interrelated (or even interdependent) spectrum issues and the respective regulatory environments.

The relationships between and among systems and devices can be broadly described as follows:

– *The personal area domain*: This consists of communications between terminal and peripheral devices that move with the user and communicate directly with each other (e.g. communication between headset and mobile terminal).

– *The immediate area domain*: This comprises direct communication between a user device and other devices (e.g. communication of a refrigerator, digital television, home gateway, etc.) in the immediate environment of the user. This communication covers a maximum range of a few metres up to several tens of metres.

– *The wide area domain*: This comprises the communication of devices via the infrastructure of network operators. One example is the communication between mobile terminals and servers in the network.

These three domains are illustrated in Fig. 3.

FIGURE 3

Communications relationships between devices in the three domains
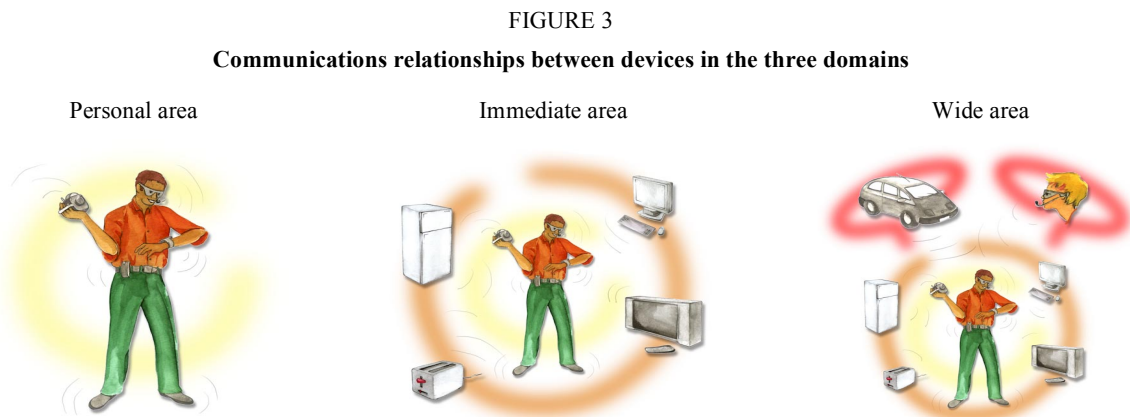
1645-03

It is important to note that different technologies, such as RLAN, short range connectivity systems, and IMT-2000, may be present in a single device operating across various networks at any particular time. For example, a personal digital assistant may contain multiple radio interfaces enabling it to communicate with a mobile terminal (personal area domain); a private or public RLAN (immediate area domain); or a wide-area service provider, such as a mobile (cellular) network (wide area domain).

From a service provision perspective, the domains share some common characteristics. Wireless service provision will be characterized by global mobile access (terminal and personal mobility), high security, high service quality and ergonomic access to personalized multimedia services for

voice, data, message, video, World Wide Web, and location-based services via one or multiple user terminal(s).

One important element in realizing this framework of integrated services, given the emerging dominant role of packet-based applications and networks, is the development of suitable adaptive packet data transfer solutions. It should be possible to support asymmetric traffic in an efficient way.

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

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

This "optimally connected anywhere, anytime" view could be realized by a network comprising a variety of interworking access systems connected to a common packet-based core network, as seen in Fig. 4.

FIGURE 4

Future network of systems beyond IMT-2000 including a variety of potential interworking access systems

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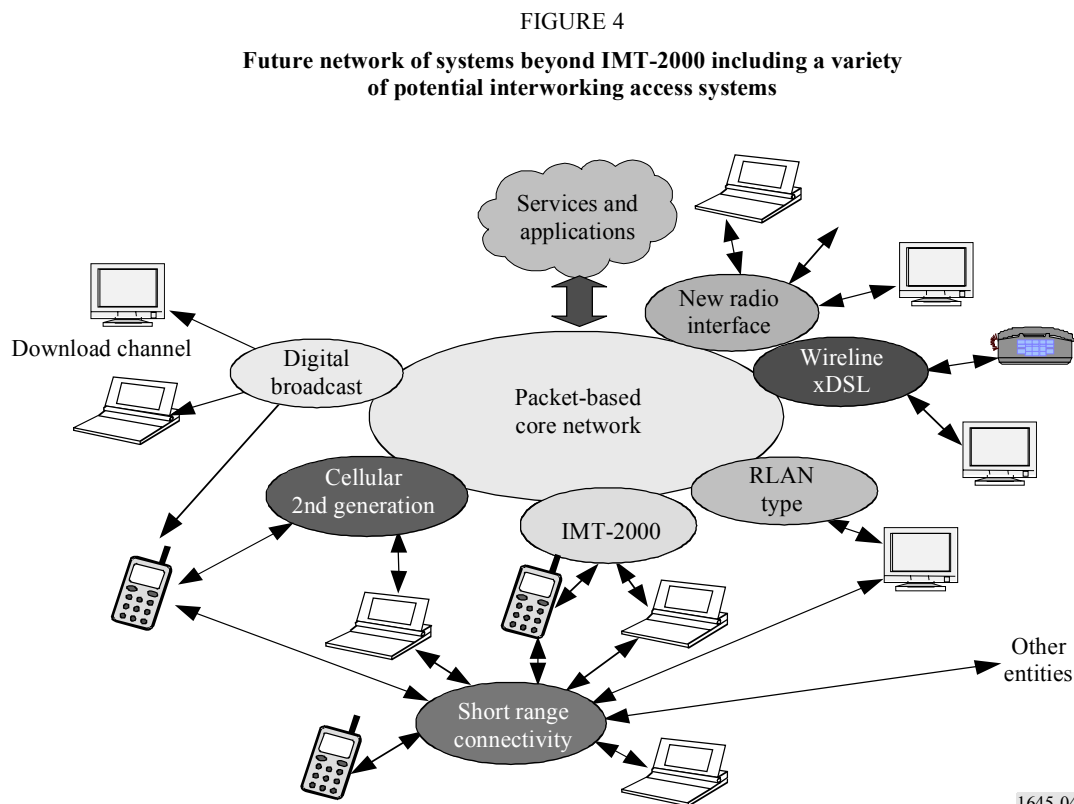
Due to the different application areas, cell ranges and radio environments, the different access systems can be organized in a layered structure (according to Fig. 5) similar to hierarchical cell structures in cellular mobile radio systems. This allows deployment of the necessary system capacity and capability where needed. Figure 5 presents an illustration of examples of the seamless interworking between different complementary access systems in a deployment area. Interworking between different access systems will be performed in terms of vertical handover or session continuation including service negotiation to adapt the application to the service capabilities of the candidate access systems (double-sided arrows). The single-ended arrows correspond to return channels for broadcast type channels. The different layers correspond to the:
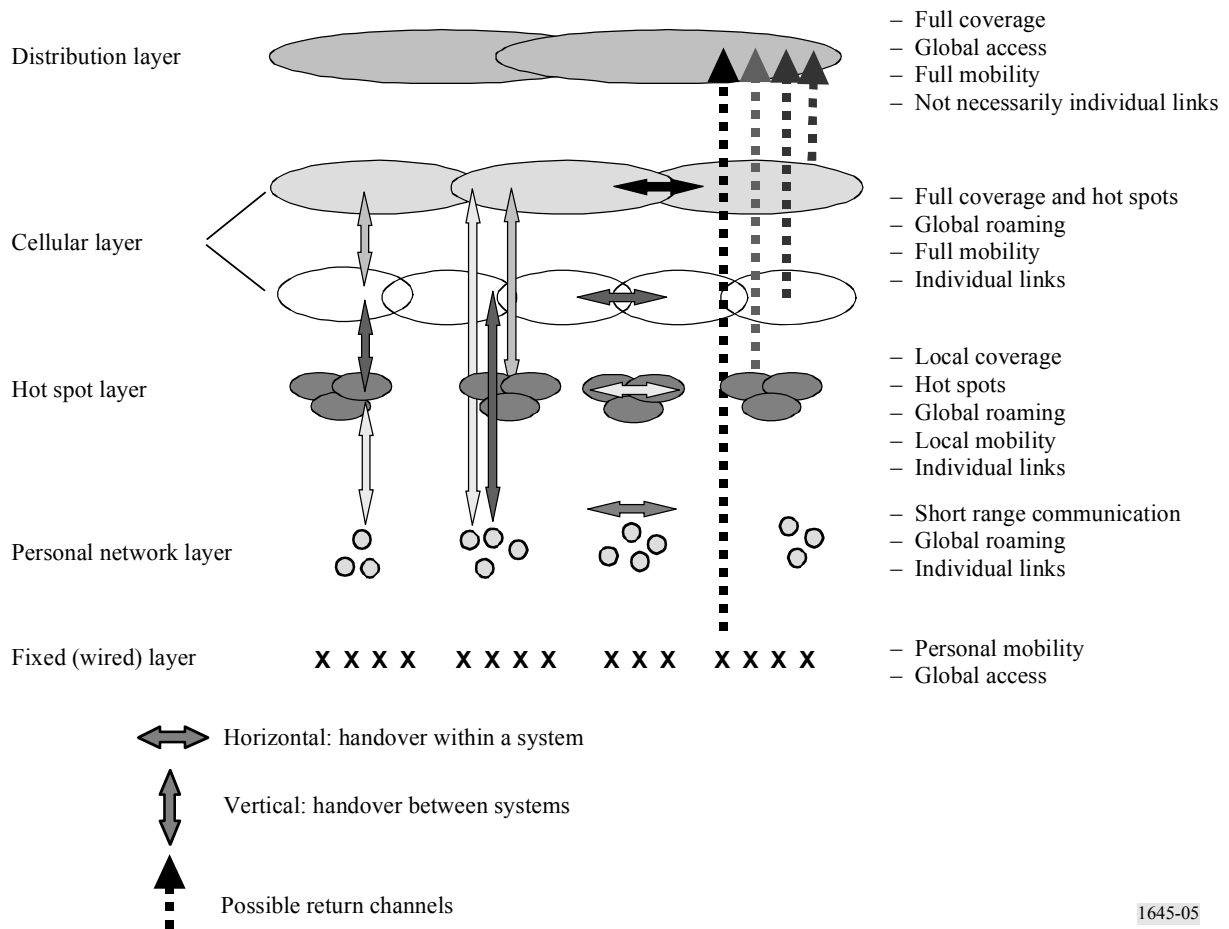
–   *distribution layer*: this layer comprises digital broadcast type systems to distribute the same information to many users simultaneously through unidirectional links. Other access systems can be used as a return channel;

–   *cellular layer*: the cellular layer may comprise several cell layers with different cell size and or different access technologies;

–   *hot spot layer*: this layer may be used for very high data rate applications, very high traffic density and individual links, e.g. in very dense urban areas, campus areas, conference centres, and airports;

–   *personal network layer*: personal area networks will support short-range direct communication between devices;

–   *fixed (wired) layer*: this layer includes any fixed wireline access system.

The enhanced IMT-2000 and the new mobile access of systems beyond IMT-2000 will be part of the cellular layer and hot spot layer. Nomadic/local wireless access of systems beyond IMT-2000 will be part of the hot spot layer.

Figure 5 illustrates a flexible and scalable environment which can be used for the allocation of system capacity in a deployment area, where one or several systems may be deployed according to need.

FIGURE 5

Illustration of complementary access systems

Distribution layer
– Full coverage
– Global access
– Full mobility
– Not necessarily individual links

Cellular layer
– Full coverage and hot spots
– Global roaming
– Full mobility
– Individual links

Hot spot layer
– Local coverage
– Hot spots
– Global roaming
– Local mobility
– Individual links

Personal network layer
– Short range communication
– Global roaming
– Individual links

Fixed (wired) layer
– Personal mobility
– Global access

Horizontal: handover within a system

Vertical: handover between systems

Possible return channels

1645-05

4.2.7 Timelines

In planning for the future development of IMT-2000 and systems beyond IMT-2000, it is important to consider the timelines associated with their realization, which depend on a number of factors:

– user trends, requirements and user demand;

– technical capabilities and technology developments;

– standards development;

– spectrum availability, including allowing sufficient time to re-locate systems that may be using proposed bands;

– regulatory considerations;

– system (mobile and infrastructure) development and deployment.

All of these factors are interrelated. The first five have been and will continue to be addressed within ITU. System development and deployment relates to the practical aspects of deploying new networks, taking into account the need to minimize additional infrastructure investment and to allow time for customer adoption of the services of a major new system, such as IMT-2000.

The timelines associated with these different factors are depicted in Fig. 6. When discussing the time phases for systems beyond IMT-2000, it is important to specify the time at which the standards are completed, when spectrum must be available, and when deployment may start.

FIGURE 6

**Phases and expected timelines for future development of IMT-2000
and systems beyond IMT-2000**
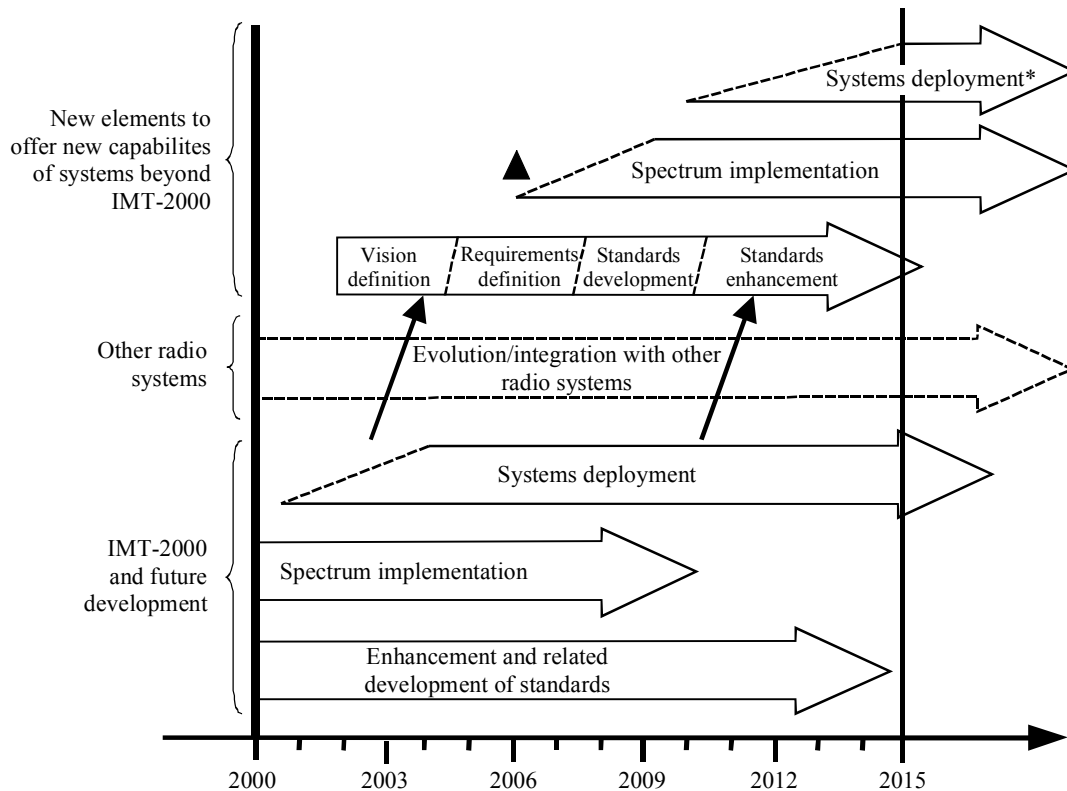
The sloped dotted lines indicate that the exact starting point of the particular subject can not yet be fixed.

▲ : Possible spectrum identification at WRC-07

* : Possible wide deployment around the year 2015 in some countries

1645-06

4.2.7.1 Medium term

In the medium-term (up to about the year 2010) it is envisaged that the future development of IMT-2000 will progress with the ongoing enhancement of the capabilities of the initial deployments, as demanded by the marketplace in addressing user needs and allowed by the status of technical developments. This phase will be dominated by the growth in traffic within the existing IMT-2000 spectrum, and the development of IMT-2000 during this time will be distinguished by incremental or evolutionary changes to the existing IMT-2000 radio interface specifications (i.e. these changes can be reflected in revisions to existing IMT-2000 ITU-R M-series Recommendations). There could be significant progress towards harmonization of the radio interfaces and the introduction of packet-based core networks.

It is envisaged that the bands identified by WRC-2000 will be made available for IMT-2000 within this time-frame, subject to user demand and other considerations.

4.2.7.2   Long term

The long term (beginning around the year 2010) is associated with the potential introduction of new radio interface(s) which could be widely deployed around the year 2015 in some countries and with capabilities significantly beyond those envisaged for IMT-2000 as it evolves during the medium term. It is envisaged that the new interface(s) will add significant new capabilities (e.g. much higher user data rates), and they may need additional frequency bands in which to operate. Evolutions in technologies, interworking between frequency bands and different access systems and improvement in spectrum efficiency may reduce the amount of additional spectrum needed. It is anticipated that certain core capabilities will be common to both enhanced IMT-2000 and systems beyond IMT-2000.

It is currently envisaged that the new radio interface(s) of systems beyond IMT-2000 will be primarily and initially intended for use in new spectrum identified by future WRCs.

4.3   Technology trends

In defining the framework and objectives for the future development of IMT-2000 and systems beyond IMT-2000, the significant technology trends need to be considered. This section identifies the technology domains in which trends can be foreseen at the time of preparation of this Recommendation. Depending on their development, evolution, realized capabilities and cost structure, each of these technology trends may or may not have an impact or be used for the systems beyond IMT-2000. It is expected that the research and development of systems beyond IMT-2000 will consider these trends and provide guidance on the applicability or influence they might have on systems beyond IMT-2000. The technology trends will be described in more detail in a separate Report.

4.3.1   System-related technologies

With respect to requirements on high data rates and high mobility, new or evolved architectures are foreseen, in particular those related to the use of packet-based architectures which will offer increased system security and reliability, intersystem mobility and interoperability capabilities.

Example key technologies:

> Voice over IP; optimization of IP for mobile radio transmission; fault-tolerant (high reliability) network architecture; seamless mobility, (inter-system handover, roaming, optimal network selection); mobile platform technology; security and privacy; cryptography; authentication and mobile electronic commerce; billing; intelligent data filtering.

4.3.2   Access network and radio interface

New concepts and radio access techniques may influence the future development of IMT-2000 and systems beyond IMT-2000. These include, but are not limited to:

–   modulation and coding schemes;

–   multiple access schemes;

–   software defined radio and reconfigurable systems;

– adaptive radio interface;

– new antenna concepts and technologies.

Example key technologies:

Software defined radio; novel access network architectures (e.g. high packet rate nodes); mobile ad hoc networks; routing algorithms; multicast; radio over fibre; handover between different radio interfaces (vertical and horizontal); dynamic QoS control; packet mobility control; robust packet transmission; distributed MAC; error correction and channel coding; adaptive and higher order modulation and link adaptation; adaptive antennas; MIMO (Multiple Input Multiple Output); multi-user detection and interference cancellation; backhaul links.

4.3.3 Utilization of spectrum

New techniques to increase spectrum utilization and spectrum efficiency, and to allow spectrum resources to be shared between users, are being studied. These studies may lead to improved frequency usage and/or to new ways to share the spectrum resource with other users or systems.

Example key technologies:

Hierarchical cell structures (including three dimensional); adaptive antennas; MIMO; adaptive dynamic channel assignment; spectrum sharing (between different operators and systems).

4.3.4 Mobile terminals

Major evolutions are foreseen in mobile terminals, with use of new components, new architectures, new hardware and software platforms, and improved user interfaces, which will together provide increased performance.

Example key technologies:

Man-machine interfaces (including "intelligent" mobile terminals); integration of mobile terminals and IT devices; mobile terminal platforms (operating systems, middlewares and application programming interfaces); autonomous subsystem architecture (separate communication and applications subsystems); advances in display devices; voice recognition; wearable terminals; software defined radio and multi-mode terminals; advances in processing power of semiconductors (as described by Moore's Law); improvements in RF devices (allowing higher operating frequencies and improved receiver sensitivity); RF MEMS (micro electro-mechanical systems); battery technology (increased energy density).

4.3.5 Applications

Applications accessed through IMT-2000 and systems beyond IMT-2000 will evolve:

– to follow the general trends of telecommunication systems;

– to adapt to the capabilities of the mobile systems and optimize service delivery in the radio environment.

Example key technologies:

> Data coding and compression techniques; dynamic variable-rate codecs; mobile agents; content description language; streaming of speech and video; APIs (application programming interfaces) and middlewares.

4.4   Spectrum implications

A critical consideration in realizing the framework for the future development of IMT-2000 and systems beyond IMT-2000 is the availability of adequate spectrum to support future services. When considering the requirements and potential frequency ranges to support these systems, it is useful to consider the timelines, services and technology trends discussed above, recognizing that these topics may be further developed in additional Recommendations and Reports. More specifically, in analysing the spectrum implications of the future development of IMT-2000 and systems beyond IMT-2000, many issues must be addressed, including, but not limited to:

–   traffic projections and requirements including ratio of asymmetry;

–   service and application requirements;

–   spectrum efficiency;

–   radio transmission characteristics (time division duplex (TDD)/frequency division duplex (FDD), duplex direction, transmit/receive separation, modulation and access schemes, etc.);

–   global roaming requirements and harmonized use of spectrum;

–   technical solutions to facilitate global roaming;

–   techniques of dynamic spectrum sharing;

–   sharing and compatibility analysis;

–   evolution of IMT-2000 systems.

With the ongoing growth in number in mobile users and the anticipated growth of data applications and bandwidth, additional spectrum may be needed. However, technology advances will allow a more efficient use of spectrum. For the determination of any additional spectrum, new analysis will be needed. This new analysis should take into account the advances in technology, traffic models and user demands. All efforts will be made to use the spectrum as efficiently as possible to limit the additional spectrum demand. The analysis must also consider the constraints associated with realizing the data rate targets, including potential availability of spectrum in suitable frequency ranges. The necessary methodology for calculation and estimations on the expected spectrum demand will be addressed in other ITU-R Recommendations.

Figure 2 illustrates the capabilities of IMT-2000 and systems beyond IMT-2000. This Recommendation only considers the spectrum implications for the new capabilities for systems beyond IMT-2000 illustrated in Fig. 2.

The spectrum demand is determined by the data rate targets, the modulation, coding, etc. methods (physical layer), advanced antenna concepts, guardbands, frequency bands, deployment conditions, among others. The necessary steps in calculating this spectrum demand include:

–   to develop a method for calculation of the spectrum demand;

–   the assessment of potential new technologies for efficient use of the spectrum; and

–   the investigation of new methods for reuse and sharing of spectrum.

4.4.1   Preferred frequency bands

It is expected that IMT-2000 and its enhancements will continue to operate in the bands identified by WARC-92 and WRC-2000. 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 the new mobile access capability, data rates higher than IMT-2000 would result in a smaller cell size. The cell size also decreases at higher frequencies. 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 the wide area mobility capability of systems beyond IMT-2000 to be reasonably close to the bands already identified for IMT-2000. Since it is becoming increasingly difficult to find suitable spectrum for new applications, especially if a wide bandwidth or paired spectrum is needed, it is necessary to identify the spectrum at an early stage so that it can be made available for use in a timely manner.

Internationally agreed frequency bands will encourage the adoption of systems beyond IMT-2000 by facilitating global roaming and reducing equipment cost through global economies of scale. Common global spectrum is a preferred objective.

4.4.2   Bandwidth considerations

To fulfil the framework of systems beyond IMT-2000, sufficient spectrum should be available both for the launch of services and, later, to carry the predicted traffic for systems beyond IMT-2000.

The factors influencing the bandwidth needed for launch of service include:

–   the RF bandwidth of a single carrier;

–   reuse factor;

–   duplex technique (ranging from slightly greater than one for TDD to two for symmetrical FDD);

–   the number of carrier frequencies which an operator needs to operate an efficient network (taking into account technology trends, for example in hierarchical cell structures);

–   the number of operators;

–   an allowance for guardbands;

–   whether the spectrum is segmented between network operators or "pooled" and also whether it is shared with other radio services.

The factors influencing the bandwidth needed to carry the predicted traffic include:

–   traffic models and QoS requirements (including peak traffic demand, average traffic demand and allowed latency);

–   duplex technique;

–   the spectrum efficiency of the radio interface (including the reuse factor);

–   trunking efficiency;

–   technologies for spectrum reuse within a cell, such as adaptive antennas and MIMO;

–   an allowance for guardbands.

It is likely that not all of the spectrum required in the longer term for systems beyond IMT-2000 will be available for the initial launch of service. It is therefore desirable that systems beyond IMT-2000 may be launched using less spectrum than that expected to be needed later to support the predicted traffic.

Spectrum will be more encumbered, less available and fully utilized. Access to bands with favourable propagation characteristics is likely to be difficult. Therefore, spectrum (as the radio natural resource) may not be used as it is today, because the efficient use of scarce frequency bands and the convergence of services may require the need for dynamic spectrum sharing. This has to be taken into account in the evolution to enhanced IMT-2000 systems and systems beyond IMT-2000.

5   Recommendations

The ITU Radiocommunication Assembly,

recommends

5.1   Objectives

–   that enhanced IMT-2000 systems should support a steady and continuous evolution of new applications, products, and services through improvements in data rates and enhancements to the existing IMT-2000 radio interfaces;

–   that the framework for systems beyond IMT-2000 should be realized by the functional fusion of existing, enhanced and newly developed elements of IMT-2000, nomadic wireless access systems and other wireless systems with high commonality and seamless interworking and interoperability;

– that the development of new radio interface(s) should recognize that any new wireless access technology for systems beyond IMT-2000 may be mainly used in conjunction with pre-IMT-2000, IMT-2000, and enhanced IMT-2000 wireless access technologies (as detailed in Recommendation ITU-R M.1457) and other existing radio systems;

– that the potential new radio interface(s) of systems beyond IMT-2000 should support data rates higher than enhanced IMT-2000, with either an adaptive interface or multiple interfaces with maximum commonality;

– that the services offered over the wireless access technologies comprising IMT-2000 and systems beyond IMT-2000 should appear as seamless and as common as possible from the user's perspective, taking into account the limitations of particular wireless access technologies and requirements of the user, so that the user may not need to be concerned with the underlying technology being used at a particular time or location.

5.2 Framework of future work

a) Review of user trends

– that once mobile multimedia data services have been widely deployed and sufficient user experience gained, the characteristics and trends information from such experience be considered in re-evaluating the user requirements for the future development of IMT-2000 and systems beyond IMT-2000;

– that reviews of user trends be undertaken as and when required and reflected in possible future revisions to this Recommendation.

b) Research

– that research, on a global basis, be undertaken to address the framework detailed in this Recommendation and into a potential new wireless access technique(s) for the terrestrial component;

– that a global cooperation of the various wireless research fora is encouraged;

– that work should be undertaken to enhance the interrelation between satellite and terrestrial mobile systems, particularly on seamless interworking between them;

– that research on the specifications for the future development of IMT-2000 and systems beyond IMT-2000 consider how these systems may relate to other radio technologies and systems and how all systems will continue to evolve;

– that the goals for the capability of systems beyond IMT-2000 are up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access around the year 2010. These goals are targets for research and investigation and may be further developed in other ITU Recommendations, and may be revised in the light of future studies;

–   that new technologies and technology trends be studied for their possible contributions to the effective and efficient realization of the framework for the future development of IMT-2000 and systems beyond IMT-2000;

–   that work should be undertaken to further improve the efficient and effective use of spectrum for the future development of IMT-2000 and systems beyond IMT-2000.

c)   Spectrum

–   that the need for spectrum for the future development of IMT-2000 and systems beyond IMT-2000, beyond that already identified in the Radio Regulations for IMT-2000, may be considered in time for future WRCs;

–   that user demand requirements are considered when determining future potential frequency ranges;

–   that the technical requirements to facilitate the cost-effective deployment of a new radio interface(s) to satisfy the new mobile access and nomadic/local wireless access capabilities are considered when determining potential frequency ranges;

–   that globally common spectrum and harmonized frequency arrangements should continue to be sought for the future development of IMT-2000 and systems beyond IMT-2000.

d)   Standardization

–   that detailed standardization of the radio interface(s) should take into account the frequency band(s) in which it is intended to be used;

–   that global and open standardization of the radio interface specifications should continue in the future to realize the benefits of mass market and ensure interoperable equipment so that users, operators, manufacturers, etc. can continue to benefit from mobile communications;

–   that the level and type of standardization should be adapted to meet technical and user requirements at that time;

–   that standardization should be performed in a timely manner prior to system deployment and should take into account the availability of spectrum and user considerations.

5.3   Focus areas for further study

–   that research forums and other external organizations wishing to contribute to the future development of IMT-2000 and systems beyond IMT-2000, are encouraged to focus especially in the following key areas:

        a)   radio interface(s) and their interoperability;

        b)   access network related issues;

        c)   spectrum related issues;

        d)   traffic characteristics;

        e)   user estimations.

A more detailed description of the research topics is found via a hyperlink at: http://www.itu.int/itu-r/study-groups/rsg8/rwp8f/index.asp.